

BEGINNERS' BOTANY

WESTERN EDITION



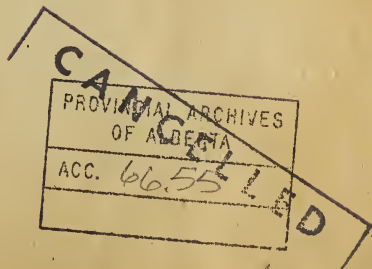
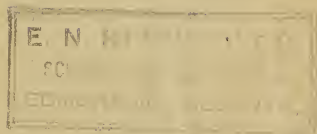
1. *Chlorophyll a*
 2. *Chlorophyll b*
 3. *Chlorophyll c*
 4. *Chlorophyll d*
 5. *Chlorophyll e*
 6. *Chlorophyll f*
 7. *Chlorophyll g*
 8. *Chlorophyll h*
 9. *Chlorophyll i*
 10. *Chlorophyll j*
 11. *Chlorophyll k*
 12. *Chlorophyll l*
 13. *Chlorophyll m*
 14. *Chlorophyll n*
 15. *Chlorophyll o*
 16. *Chlorophyll p*
 17. *Chlorophyll q*
 18. *Chlorophyll r*
 19. *Chlorophyll s*
 20. *Chlorophyll t*
 21. *Chlorophyll u*
 22. *Chlorophyll v*
 23. *Chlorophyll w*
 24. *Chlorophyll x*
 25. *Chlorophyll y*
 26. *Chlorophyll z*
 27. *Chlorophyll aa*
 28. *Chlorophyll ab*
 29. *Chlorophyll ac*
 30. *Chlorophyll ad*
 31. *Chlorophyll ae*
 32. *Chlorophyll af*
 33. *Chlorophyll ag*
 34. *Chlorophyll ah*
 35. *Chlorophyll ai*
 36. *Chlorophyll aj*
 37. *Chlorophyll ak*
 38. *Chlorophyll al*
 39. *Chlorophyll am*
 40. *Chlorophyll an*
 41. *Chlorophyll ao*
 42. *Chlorophyll ap*
 43. *Chlorophyll aq*
 44. *Chlorophyll ar*
 45. *Chlorophyll as*
 46. *Chlorophyll at*
 47. *Chlorophyll au*
 48. *Chlorophyll av*
 49. *Chlorophyll aw*
 50. *Chlorophyll ax*
 51. *Chlorophyll ay*
 52. *Chlorophyll az*
 53. *Chlorophyll ba*
 54. *Chlorophyll bb*
 55. *Chlorophyll bc*
 56. *Chlorophyll bd*
 57. *Chlorophyll be*
 58. *Chlorophyll bf*
 59. *Chlorophyll bg*
 60. *Chlorophyll bh*
 61. *Chlorophyll bi*
 62. *Chlorophyll bj*
 63. *Chlorophyll bk*
 64. *Chlorophyll bl*
 65. *Chlorophyll bm*
 66. *Chlorophyll bn*
 67. *Chlorophyll bo*
 68. *Chlorophyll bp*
 69. *Chlorophyll bq*
 70. *Chlorophyll br*
 71. *Chlorophyll bs*
 72. *Chlorophyll bt*
 73. *Chlorophyll bu*
 74. *Chlorophyll bv*
 75. *Chlorophyll bw*
 76. *Chlorophyll bx*
 77. *Chlorophyll by*
 78. *Chlorophyll bz*
 79. *Chlorophyll ca*
 80. *Chlorophyll cb*
 81. *Chlorophyll cc*
 82. *Chlorophyll cd*
 83. *Chlorophyll ce*
 84. *Chlorophyll cf*
 85. *Chlorophyll cg*
 86. *Chlorophyll ch*
 87. *Chlorophyll ci*
 88. *Chlorophyll cj*
 89. *Chlorophyll ck*
 90. *Chlorophyll cl*
 91. *Chlorophyll cm*
 92. *Chlorophyll cn*
 93. *Chlorophyll co*
 94. *Chlorophyll cp*
 95. *Chlorophyll cq*
 96. *Chlorophyll cr*
 97. *Chlorophyll cs*
 98. *Chlorophyll ct*
 99. *Chlorophyll cu*
 100. *Chlorophyll cv*
 101. *Chlorophyll cw*
 102. *Chlorophyll cx*
 103. *Chlorophyll cy*
 104. *Chlorophyll cz*
 105. *Chlorophyll da*
 106. *Chlorophyll db*
 107. *Chlorophyll dc*
 108. *Chlorophyll dd*
 109. *Chlorophyll de*
 110. *Chlorophyll df*
 111. *Chlorophyll dg*
 112. *Chlorophyll dh*
 113. *Chlorophyll di*
 114. *Chlorophyll dj*
 115. *Chlorophyll dk*
 116. *Chlorophyll dl*
 117. *Chlorophyll dm*
 118. *Chlorophyll dn*
 119. *Chlorophyll do*
 120. *Chlorophyll dp*
 121. *Chlorophyll dq*
 122. *Chlorophyll dr*
 123. *Chlorophyll ds*
 124. *Chlorophyll dt*
 125. *Chlorophyll du*
 126. *Chlorophyll dv*
 127. *Chlorophyll dw*
 128. *Chlorophyll dx*
 129. *Chlorophyll dy*
 130. *Chlorophyll dz*
 131. *Chlorophyll ea*
 132. *Chlorophyll eb*
 133. *Chlorophyll ec*
 134. *Chlorophyll ed*
 135. *Chlorophyll ee*
 136. *Chlorophyll ef*
 137. *Chlorophyll eg*
 138. *Chlorophyll eh*
 139. *Chlorophyll ei*
 140. *Chlorophyll ej*
 141. *Chlorophyll ek*
 142. *Chlorophyll el*
 143. *Chlorophyll em*
 144. *Chlorophyll en*
 145. *Chlorophyll eo*
 146. *Chlorophyll ep*
 147. *Chlorophyll eq*
 148. *Chlorophyll er*
 149. *Chlorophyll es*
 150. *Chlorophyll et*
 151. *Chlorophyll eu*
 152. *Chlorophyll ev*
 153. *Chlorophyll ew*
 154. *Chlorophyll ex*
 155. *Chlorophyll ey*
 156. *Chlorophyll ez*
 157. *Chlorophyll fa*
 158. *Chlorophyll fb*
 159. *Chlorophyll fc*
 160. *Chlorophyll fd*
 161. *Chlorophyll fe*
 162. *Chlorophyll ff*
 163. *Chlorophyll fg*
 164. *Chlorophyll fh*
 165. *Chlorophyll fi*
 166. *Chlorophyll fj*
 167. *Chlorophyll fk*
 168. *Chlorophyll fl*
 169. *Chlorophyll fm*
 170. *Chlorophyll fn*
 171. *Chlorophyll fo*
 172. *Chlorophyll fp*
 173. *Chlorophyll fq*
 174. *Chlorophyll fr*
 175. *Chlorophyll fs*
 176. *Chlorophyll ft*
 177. *Chlorophyll fu*
 178. *Chlorophyll fv*
 179. *Chlorophyll fw*
 180. *Chlorophyll fx*
 181. *Chlorophyll fy*
 182. *Chlorophyll fz*
 183. *Chlorophyll ga*
 184. *Chlorophyll gb*
 185. *Chlorophyll gc*
 186. *Chlorophyll gd*
 187. *Chlorophyll ge*
 188. *Chlorophyll gf*
 189. *Chlorophyll gg*
 190. *Chlorophyll gh*
 191. *Chlorophyll gi*
 192. *Chlorophyll gj*
 193. *Chlorophyll gk*
 194. *Chlorophyll gl*
 195. *Chlorophyll gm*
 196. *Chlorophyll gn*
 197. *Chlorophyll go*
 198. *Chlorophyll gp*
 199. *Chlorophyll gq*
 200. *Chlorophyll gr*
 201. *Chlorophyll gs*
 202. *Chlorophyll gt*
 203. *Chlorophyll gu*
 204. *Chlorophyll gv*
 205. *Chlorophyll gw*
 206. *Chlorophyll gx*
 207. *Chlorophyll gy*
 208. *Chlorophyll gz*
 209. *Chlorophyll ha*
 210. *Chlorophyll hb*

George H. Tyrell
George H. Tyrell

EX LIBRIS
UNIVERSITATIS
ALBERTAE NSIS



A 66.55



BEGINNERS' BOTANY



BOUQUET OF BEARDED WHEAT

BEGINNERS' BOTANY

BY

L. H. BAILEY

ADAPTED FOR CANADIAN SCHOOLS BY

B. J. HALES, B.A.

PRINCIPAL, NORMAL SCHOOL, BRANDON

AUTHORIZED FOR USE IN THE PROVINCES OF MANITOBA
AND SASKATCHEWAN

Toronto

THE MACMILLAN COMPANY OF CANADA, LIMITED

1921

COPYRIGHT, CANADA, 1915.

BY THE MACMILLAN COMPANY OF CANADA, LIMITED.

LIBRARY
UNIVERSITY OF ALBERTA

PREFACE

IN all teaching of plants and animals to beginners, the plants themselves and the animals themselves should be made the theme, rather than any amount of definitions and of mere study in books. The book will be very useful in guiding the way, in arranging the subjects systematically, and in explaining obscure points; but if the pupil does not know the living and growing plants when he has completed his course in botany, he has not acquired very much that is worth the while.

It is well to acquaint the beginner at first with the main features of the entire plant rather than with details of its parts. He should at once form a mental picture of what the plant is, and what are some of its broader adaptations to the life that it leads. In this book, the pupil starts with the entire branch or the entire plant. It is sometimes said that the pupil cannot grasp the idea of struggle for existence until he knows the names and uses of the different parts of the plant. This is an error, although well established in present-day methods of teaching.

Another very important consideration is to adapt the statement of any fact to the understanding of a beginner. It is easy, for example, to fall into technicalities when discussing osmosis; but the minute explanations would mean nothing to the beginner and their use would tend to confuse the picture which it is necessary to leave in the pupil's mind. Even the use of technical forms of expression would probably not go far enough to satisfy the trained physicist.

It is impossible ever to state the last thing about any proposition. All knowledge is relative. What is very elementary to one mind may be very technical and advanced to another. It is neither necessary nor desirable to safeguard statements to the beginner by such qualifications as will make them satisfactory to the critical expert in science. The teacher must understand that while accuracy is always essential, the *degree of statement* is equally important when teaching beginners.

The value of biology study lies in the work with the actual objects. It is not possible to provide specimens for every point in the work, nor is it always desirable to do so; for the beginning pupil may not be able to interest himself in the objects, and he may become immersed in details before he has arrived at any general view or reason of the subject. Great care must be exercised that the pupil is not swamped. Mere book work or memory stuffing is useless, and it may dwarf or divert the sympathies of active young minds.

The present tendency in secondary education is away from the formal technical completion of separate subjects and towards the developing of a workable training in the activities that relate the pupil to his own life. In the natural science field, the tendency is to attach less importance to botany and zoölogy and physiology as such, and to lay greater stress on the processes and adaptations of life as expressed in plants and animals and men. This tendency is a revolt against the laboratory method and research method of the college as it has been impressed into the common schools, for it is not uncommon for the pupil to study botany without really knowing plants, or physiology without knowing himself. Education that is not applicable, that does not put the pupil into touch with

the living knowledge and the affairs of his time, may be of less educative value than the learning of a trade in a shop. We are beginning to learn that the ideals and the abilities should be developed out of the common surroundings and affairs of life rather than imposed on the pupil as a matter of abstract, unrelated theory.

It is much better for the beginning pupil to acquire a real conception of a few central principles and points of view respecting common forms that will enable him to tie his knowledge together and organize it and apply it, than to familiarize himself with any number of mere facts about the lower forms of life which, at the best, he can know only indirectly and remotely. If the pupil wishes to go farther in later years, he may then take up special groups and phases.

CONTENTS

CHAPTER

I. NO TWO PLANTS OR PARTS ARE ALIKE	I
II. THE STRUGGLE TO LIVE	4
III. SURVIVAL OF THE FIT	7
IV. PLANT SOCIETIES	9
V. THE PLANT BODY	15
VI. SEEDS AND GERMINATION	20
VII. THE ROOT—THE FORMS OF ROOTS	32
VIII. THE ROOT—FUNCTION AND STRUCTURE	38
IX. THE STEM—KINDS AND FORMS—PRUNING	49
X. THE STEM—ITS GENERAL STRUCTURE	59
XI. LEAVES—FORM AND POSITION	73
XII. LEAVES—STRUCTURE AND ANATOMY	86
XIII. LEAVES—FUNCTION OR WORK	92
XIV. DEPENDENT PLANTS	106
XV. WINTER AND DORMANT BUDS	111
XVI. BUD PROPAGATION	119
XVII. HOW PLANTS CLIMB	125
XVIII. THE FLOWER—ITS PARTS AND FORMS	129
XIX. THE FLOWER—FERTILIZATION AND POLLINATION	140
XX. FLOWER-CLUSTERS	151
XXI. FRUIT	159
XXII. DISPERSAL OF SEEDS	168
XXIII. WEEDS	172
XXIV. FIELD AND GARDEN CROPS	181
GLOSSARY	201
INDEX	211

BEGINNERS' BOTANY

CHAPTER I

NO TWO PLANTS OR PARTS ARE ALIKE

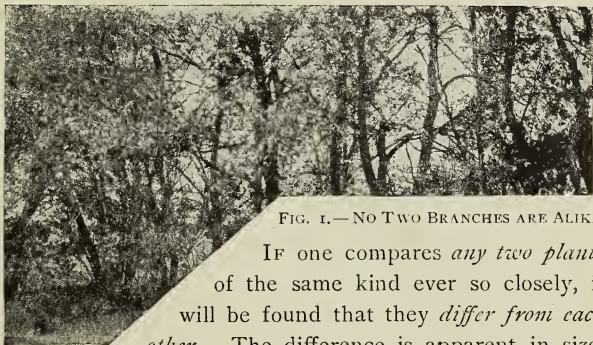


FIG. 1.—NO TWO BRANCHES ARE ALIKE.

IF one compares *any two plants* of the same kind ever so closely, it will be found that they *differ from each other*. The difference is apparent in size, form, color, mode of branching, number of leaves, number of flowers, vigor, season of maturity, and the like; or, in other words, all plants and animals *vary from an assumed or standard type*.

If one compares *any two branches or twigs* on a tree, it will be found that they differ in size, age, form, vigor, and in other ways (Fig. 1).

If one compares *any two leaves*, it will be found that they are unlike in size, shape, color, veining, hairiness, markings, cut of the margins, or other small features. In some cases (as in Fig. 2) the differences are so great as readily to be seen in a small black-and-white drawing.

If the pupil extends his observation to animals, he will still find the same truth; for probably *no two living objects are exact duplicates*. If any person finds two objects that he thinks to be exactly alike, let him set to work to



FIG. 2.—NO TWO LEAVES ARE ALIKE. Three leaves off the same raspberry bush.

discover the differences, remembering that *nothing in nature is so small or apparently trivial as to be overlooked*.

Variation, or differences between organs and also between organisms, is one of the most significant facts in nature.

SUGGESTIONS.—The first fact that the pupil should acquire about plants is that no two are alike. The way to apprehend this great fact is to see a plant accurately and then to compare it with

another plant of the same species or kind. In order to direct and concentrate the observation, it is well to set a certain number of attributes or marks or qualities to be looked for. Suppose any two or more plants of corn are compared in the following points, the pupil endeavoring to determine whether the parts exactly agree. See that the observation is close and accurate.

If corn plants are not available use some other plants.

- (1) Height of the plant.
- (2) Does it branch? How many secondary stems or "suckers" from one root?
- (3) Shade or color.
- (4) How many leaves?
- (5) Arrangement of leaves on stem.
- (6) Measure length and breadth of six main leaves.
- (7) Number and position of ears; color of silks.
- (8) Size of tassel, and number and size of its branches.
- (9) Stage of maturity or ripeness of plant.
- (10) Has the plant grown symmetrically, or has it been crowded by other plants or been obliged to struggle for light or room?
- (11) Note all unusual or interesting marks or features.
- (12) Always make note of comparative vigor of the plants.

NOTE TO TEACHER. — The teacher should always insist on *personal work* by the pupil. It should be a part of the teacher's preparation for this work to have suitable plants for study growing in the school garden. Let the living plants be studies.

Notebooks. — Insist that the pupils make full notes and preserve these notes in suitable books. The pupil should draw what he sees, even though he is not expert with the pencil. The drawing should not be made for looks, but to aid the pupil in his orderly study of the object; it should be a means of self-expression.

Laboratory. — Every school, however small, should have a laboratory or work-room. This work-room may be nothing more than a table at one side of the room where the light is good. Here the specimens may be ranged and studied. Often an aquarium and terrarium may be added. A cabinet or set of shelves should be provided for a museum and collection, but the museum specimen should not be allowed to take the place of the living plant.

The laboratory may be in part out of doors, as a school garden.

CHAPTER II

THE STRUGGLE TO LIVE

EVERY plant and animal is *exposed to unfavorable conditions*. It is obliged to contend with these conditions in order to live.

No two plants or parts of plants are identically exposed to the conditions in which they live. The large branches

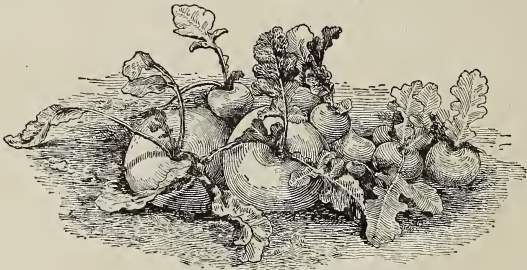


FIG. 3.—A BATTLE FOR LIFE.

in Fig. 1 probably had more room and a better exposure to light than the smaller ones. Probably no two of the leaves in Fig. 2 are equally exposed to light, or enjoy identical advantages in relation to the food that they receive from the tree.

Examine any tree to determine under what advantages or disadvantages any of the limbs may live. Examine similarly the different plants in a garden row (Fig. 3); or the different bushes in a thicket; or the different trees in a wood.

The plant meets its conditions by *succumbing to them* (that is, by dying), or by *adapting itself to them*.

The tree *meets the cold* by ceasing its active growth, hardening its tissues, dropping its leaves. Many herbaceous or soft-stemmed plants meet the cold by dying to the ground and withdrawing all life into the root parts. Some plants meet the cold by dying outright and providing abundance of seeds to perpetuate the kind next season.



FIG. 4.—THE REACH FOR LIGHT OF A TREE ON THE EDGE OF A WOOD.

Plants *adapt themselves to light* by growing towards it (Fig. 4); or by hanging their leaves in such position that they catch the light; or, in less sunny places, by expanding their leaf surface, or by greatly lengthening their stems so as to overtop their fellows, as do trees and vines.

The adaptations of plants will afford a fertile field of study as we proceed.

Struggle for existence and adaptation to conditions are among the most significant facts in nature.

The sum of all the conditions in which a plant or an animal is placed is called its **environment**, that is, its surroundings. The environment comprises the conditions of climate, soil, moisture, exposure to light, relation to food supply, contention with other plants or animals. *The organism adapts itself to its environment, or else it weakens or dies.* Every weak branch or plant has undergone some hardship that it was not wholly able to withstand.

SUGGESTIONS. — 1. The pupil should study any plant, or branch of a plant, with reference to the position or condition under which it grows, and compare one plant or branch with another. With animals, it is common knowledge that every animal is alert to avoid or to escape danger, or to protect itself. It is well to begin with a branch of a tree, as in Fig. 1. Note that no two parts are alike (Chap. I). Note that some are large and strong and that these stand farthest towards light and room. Some are very small and weak, barely able to live under the competition. Some have died.

2. Let the pupil examine the top of any low tree with dense foliage and answer the following: (a) Are there any dead branches? (b) If there are dead branches, where are they situated? (c) Why have they died? (d) How does the tree examined compare with others with less dense foliage?

3. If the pupil has access to a forest or grove, let him examine the trunks of the trees to see if they have any branches, or if not, why? If they have, are they living or dead? Why?

4. Plant some garden seeds and leave part of the row unthinned. Compare the plants with those where the row has been thinned.

5. Let the pupil report any cases of struggle between plants which he has observed.

6. Why does the farmer destroy weeds growing among potatoes?

CHAPTER III

THE SURVIVAL OF THE FIT

THE plants that most perfectly meet their conditions are able to persist. *They perpetuate themselves.* Their offspring are likely to inherit some of the attributes that enabled them successfully to meet the battle of life. *The fit* (those best adapted to their conditions) *tend to survive.*

Adaptation to conditions depends on the fact of variation; that is, if plants were perfectly rigid or invariable (all exactly alike) they could not meet new conditions. Conditions are necessarily new for every organism. *It is impossible to picture a perfectly inflexible and stable succession of plants or animals.*

Breeding. — *Man is able to modify plants and animals.* All our common domestic animals are very unlike their original ancestors. So all our common and long-cultivated plants have varied from their ancestors. Even in some plants that have been in cultivation less than a century the change is marked: compare the cultivated red raspberry with its common wild ancestor, or the cultivated blackberry with the wild form.

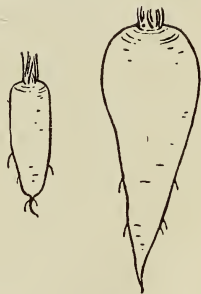


FIG. 5. — DIFFERENT TYPES OF CARROT PRODUCED BY SELECTION.

By choosing seeds from a plant that pleases him, the breeder may be able, under given conditions, to produce



FIG. 6.—FLAX BREEDING.

A is a plant grown for seed production;
B, for fiber production. Why?

selection of seed. He may select kernels from the best plant of wheat in the field, and also from the poorest plant, — having reference not so much to mere incidental size and vigor of the plants that may be due to accidental conditions in the field, as to the apparently constitutional strength and size, number and size of heads, perfectness of heads and kernels, habit of the plant as to suckering, and the like. The seeds may be saved and sown the next year. Every crop can no doubt be very greatly improved by a careful process of selection extending over a series of years. Crops are increased in yield in three ways: by better general care; by enriching the land in which they grow; by attention to breeding.

numbers of plants with more or less of the desired qualities; from the best of these, he may again choose; and so on until the race becomes greatly improved (Figs. 5, 6, 7). This process of continuously choosing the most suitable plants is known as **selection**. A somewhat similar process proceeds in wild nature, and it is then known as **natural selection**.

SUGGESTIONS.
 — Every pupil should undertake at least one simple experiment in selection.



FIG. 7.—BREEDING.

A, effect from breeding from smallest grains (after four years), average head; *B*, result from breeding from the plumpest and heaviest grains (after four years), average head.

CHAPTER IV

PLANT SOCIETIES

IN the long course of time in which plants have been accommodating themselves to the varying conditions in which they are obliged to grow, *they have become adapted to every different environment*. Certain plants, therefore, may live together or near each other, all enjoying the same general conditions and surroundings. These aggregations of plants that are adapted to similar general conditions are known as plant societies.

Moisture and temperature are the leading factors in determining plant societies. The great geographical societies or aggregations of the plant world may conveniently be associated chiefly with the moisture supply, as: *wet-region societies*, comprising aquatic and bog vegetation (Fig. 8); *arid-region societies*, comprising desert and most sand-region vegetation; *mid-region societies*, comprising the mixed vegetation in intermediate regions (Fig. 9), this being the commonest type. Much of the characteristic scenery of any place is due to its plant societies. Arid-region plants usually have small and hard leaves, apparently preventing too rapid loss of water. Usually, also, they are characterized by stiff growth, hairy covering, spines, or a much-contracted plant-body, and often by large underground parts for the storage of water.

Plant societies may also be distinguished with reference to latitude and temperature. There are *tropical societies*, *temperate-region societies*, *boreal* or *cold-region societies*.

With reference to altitude, societies might be classified as *lowland* (which are chiefly wet-region), *intermediate* (chiefly mid-region), *subalpine* or *mid-mountain* (which are chiefly boreal), *alpine* or *high-mountain*.

The above classifications have reference chiefly to great geographical floras or societies. But there are *societies within societies*. There are small societies coming within the experience of every person who has ever seen plants



FIG. 8. — A WET-REGION SOCIETY.

growing in natural conditions. There are roadside, fence-row, lawn, thicket, pasture, dune, woods, cliff, barn-yard societies. *Every different place has its characteristic vegetation*. Note the smaller societies in Figs. 8 and 9. In the former are two societies of water or marsh plants. In the latter there are grass and bush and woods societies.

Some Details of Plant Societies. — Societies may be composed of *scattered and intermingled plants*, or of dense *clumps or groups of plants*. Dense clumps or groups are usually made up of one kind of plant, and they are then

called colonies. Colonies of most plants are transient: after a short time other plants gain a foothold amongst them, and an intermingled society is the outcome. Marked exceptions to this are grass colonies and forest colonies, in which one kind of plant may hold its own for years and centuries.

In a large newly cleared area, plants usually *first establish themselves in dense colonies*. Note the great patches

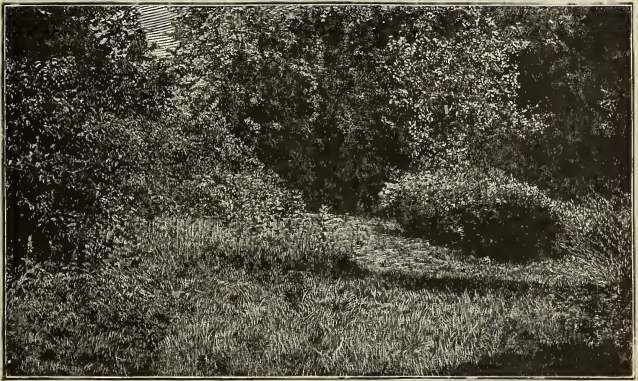


FIG. 9. — A MID-REGION SOCIETY.

of nettles and forget-me-nots around the edges of low places, of tumbling mustard, pigweed, stinkweed, and peppergrass in neglected fields, and also the rank growth of Russian pigweed and false ragweed in vacant lots or along the edges of recently graded roads.

The competition amongst themselves and with their neighbors finally breaks up the colonies, and a *mixed and intermingled flora is generally the result*.

In many parts of the world the *general tendency of neglected areas is to run into forest*. All plants rush for the

cleared area. Here and there bushes gain a foothold. Young trees come up ; in time these shade the bushes and gain the mastery. Sometimes the area grows to poplars or birches, and people wonder why the original forest trees do not return ; but these forest trees may be growing unobserved here and there in the tangle, and in the slow processes of time the poplars perish — for they are short-lived — and the original forest may be replaced. Whether one kind of forest or another returns will depend partly on the kinds that are most seedful in that vicinity and which, therefore, have sown themselves most profusely. Much depends, also, on the kind of undergrowth that first springs up, for some young trees can endure more or less shade than others.

Some plants *associate*. They grow together. This is possible largely because they diverge or differ in charac-

ter. Plants associate in two ways : *by growing side by side ; by growing above or beneath.*

In sparsely populated societies, plants may grow alongside each other. In most cases, however, there is *overgrowth* and *undergrowth* :



FIG. 10. — OVERGROWTH AND UNDERGROWTH IN THREE SERIES, — trees, bushes, grass.

one kind grows beneath another. Plants that have become adapted to shade are usually undergrowths. In a cat-tail swamp, grasses and other narrow-leaved plants grow in the bottom, but they are usually unseen by the casual

observer. Note the undergrowth in woods or under trees (Fig. 10). Observe that in pine and spruce forests there is almost no undergrowth, partly because there is very little light.

On the same area the societies may *differ at different times of the year*. There are spring, summer, and fall societies. The knoll which is cool with grass and strawberries in June may be aglow with goldenrod in September. If the bank is examined in May, look for the young plants that are to cover it in July and October; if in September, find the dead stalks of the flora of May. What succeeds the early anemone, three-flowered avens, sweet coltsfoot, violets, and buttercups of spring? What precedes the wild sunflowers, ragweed, asters, and goldenrod of fall?

The Landscape. — To a large extent the *color of the landscape* is determined by the character of the plant societies. Evergreen societies remain green, but the shade of green varies from season to season; it is bright and soft in spring, becomes dull in midsummer and fall, and assumes a dull yellow-green or a black-green in winter. Deciduous societies vary remarkably in color — from the dull browns and grays of winter to the brown-greens and olive-greens of spring, the staid greens of summer, and the more brilliant colors of autumn.

The *autumn colors* are due to intermingled shades of green, yellow, and red. The coloration varies with the kind of plant, the special location, and the season. Even in the same species or kind, individual plants differ in color; and this individuality usually distinguishes the plant year by year. That is, a tree which is maroon-red this autumn is likely to exhibit that range of color every year. The autumn color is associated with the natural maturity and death of the leaf, but it is most brilliant in long and open

falls — largely because the foliage ripens more gradually and persists longer in such seasons. It is probable that the autumn tints are of no utility to the plant. *Autumn colors are not caused by frost.* Because of the long, dry falls and the great variety of plants, the autumnal color of the eastern Canadian landscape is phenomenal, while the more sudden change to cold weather probably accounts for the less brilliant hues in the West.

Ecology. — The study of the relationships of plants and animals to each other and to seasons and environments is known as **ecology** (still written *œcology* in the dictionaries). It considers the habits, habitats, and modes of life of living things — the places in which they grow, how they migrate or are disseminated, means of collecting food, their times and seasons of flowering, producing young, and the like.

SUGGESTIONS. — One of the best of all subjects for school instruction in botany is the study of plant societies. It adds definiteness and zest to excursions. Let each excursion be confined to one or two societies. Visit one day a swamp, another day a forest, another a pasture or meadow, another a roadside, another a weedy field, another a cliff or ravine. Visit shores whenever possible. Each pupil should be assigned a bit of ground — say 10 or 20 ft. square — for special study. He should make a list showing (1) how many kinds of plants it contains, (2) the relative abundance of each. The lists secured in different regions should be compared. It does not matter greatly if the pupil does not know all the plants. He may count the kinds without knowing the names. It is a good plan for the pupil to make a dried specimen of each kind for reference. The pupil should endeavor to discover why the plants grow as they do. Note what kinds of plants grow next each other; and which are undergrowth and which overgrowth; and which are erect and which wide-spreading. *Challenge every plant society.*

CHAPTER V

THE PLANT BODY

The Parts of a Plant. — Our familiar plants are made up of several distinct parts. The most prominent of these parts are *root, stem, leaf, flower, fruit, and seed*. *Familiar plants differ wonderfully in size and shape*, — from fragile mushrooms, delicate waterweeds and pond-scums, to floating leaves, soft grasses, coarse weeds, tall bushes, slender climbers, gigantic trees, and hanging moss.

The Stem Part. — In most plants there is a *main central part or shaft* on which the other or *secondary parts* are borne. This main part is the **plant axis**. Above ground, in most plants, the main plant axis bears the *branches, leaves, and flowers*; below ground, it bears the *roots*.

The rigid part of the plant, which persists over winter and which is left after leaves and flowers are fallen, is the **framework** of the plant. The framework is composed of both root and stem. When the plant is dead, the framework remains for a time, but it slowly decays. The dry winter stems of weeds are the framework, or skeleton of the plant (Figs. 11 and 12). The framework of trees is the most conspicuous part of the plant.

The Root Part. — The root bears the stem at its apex, but otherwise it normally *bears only root-branches*. The stem, however, *bears leaves, flowers, and fruits*. Those living surfaces of the plant which are most exposed to light are *green or highly colored*. The root tends to grow *downwards*, but the stem tends to grow *upward towards light*

and air. The plant is anchored or fixed in the soil by the roots. Plants have been called "earth parasites."

The Foliage Part. — The *leaves precede the flowers* in point of time or life of the plant. *The flowers always precede the fruits and seeds.* Many plants die when the seeds have matured. The whole mass of leaves of any

plant or any branch is known as its *foliage*. In some cases, as in anemone, the flowers seem to precede the leaves; but the leaves that made the food for these flowers grew the preceding year.

The Plant Generation.

—The course of a plant's life, with all the events through which the plant naturally passes, is known as the plant's **life-history**. The life-history embraces various stages, or epochs, as *dormant*



FIG. 11. — PLANT OF A
WILD SUNFLOWER.



FIG. 12 — FRAME-
WORK OF FIG. 11.

seed, germination, growth, flowering, fruiting. Some plants run their course in a few weeks or months, and some live for centuries.

The entire life-period of a plant is called a **generation**. It is the whole period from birth to normal death, without reference to the various stages or events through which it passes.

A generation begins with *the young seed*, not with germi-

nation. *It ends with death*—that is, when no life is left in any part of the plant, and only the seed or spore remains to perpetuate the kind. In a bulbous plant, as a lily or an onion, the generation does not end until the bulb dies, even though the top is dead.

When the generation is of only one season's duration, the plant is said to be **annual**. When it is of two seasons, it is **biennial**. Biennials usually bloom the second year. When of three or more seasons, the plant is **perennial**. Examples of annuals are pigweed, bean, pea, garden sunflower; of biennials, evening primrose, blue bur and burdock; of perennials, dock, most meadow grasses, cat-tail, and all shrubs and trees.

Duration of the Plant Body.—Plant structures which are more or less soft and which die at the close of the season are said to be **herbaceous**, in contradistinction to being **ligneous** or **woody**. A plant which is herbaceous to the ground is called an **herb**; but an herb may have a woody or perennial root, in which case it is called an **herbaceous perennial**. Annual plants are classed as herbs. Examples of herbaceous perennials are buttercups, bleeding heart, violet, horse-radish, dock, dandelion, goldenrod, asparagus, rhubarb, many wild sunflowers (Figs. 11, 12).

Many herbaceous perennials have *short generations*. They become weak with one or two seasons of flowering and gradually die out. Thus, red clover usually begins to fail after the second year. Gardeners know that the best bloom of hollyhock, larkspur, pink, and many other plants, is secured when the plants are only two or three years old, while pansies and sweet williams are usually classed by seedsmen as biennials, because they seldom live after the second year.

Herbaceous perennials which die away each season to bulbs or tubers, are sometimes called **pseud-annuals** (that is, *false annuals*). Of such are lily, onion, and potato.

True annuals reach old age the first year. Plants which are normally perennial *may become annual in a shorter-season climate by being killed by frost*, rather than by dying naturally at the end of a season of growth. They are climatic annuals. Such plants are called **plur-annuals** in the short-season region. Many tropical perennials are plur-



FIG. 13.—TREES. Young poplars and elms on the grounds of the Normal School, Brandon.

annuals when grown in the north, but they are treated as true annuals because they grow sufficient flowers or fruit the same season in which the seeds are sown to make them worth cultivating. The tomato and verbena are examples. Name several vegetables that are planted in gardens with the expectation that they will bear till frost comes.

Woody or ligneous plants are usually longer lived than herbs. Those that remain low and produce several or

many similar shoots from the base are called **shrubs**, as lilac, rose, honeysuckle (Fig. 14). Low and thick shrubs are **bushes**. Plants that produce one main trunk and a more or less elevated head are **trees** (Fig. 13). All shrubs and trees are perennial.

Every plant makes an effort *to propagate, or to perpetuate its kind*; and, as far as we can see, this is the end for which the plant itself lives. *The seed or spore is the final product of the plant.*



FIG. 14. — A SHRUB. Honeysuckle.

SUGGESTIONS. —

1. The teacher may assign each pupil to one plant in the school yard, or field, or in a pot, and ask him to bring out the points in the lesson.

2. The teacher may put on the board the names of many common plants and ask the pupils to classify into annuals, pseud-annuals, plur-annuals (or climatic annuals), biennials, perennials, herbaceous perennials, ligneous perennials, herbs, bushes, trees. Every plant grown on the farm should be so classified: wheat, oats, corn, brome grass, timothy, strawberry, raspberry, currant, carrot, alfalfa, flax, white clover, hops, vetch, field bean, beet, potato, onion, radish, sugar-beet, barley, cabbage, and others. Name all the kinds of trees you know.

CHAPTER VI

SEEDS AND GERMINATION

THE seed contains a *miniature plant*, or **embryo**. The embryo usually has three parts that have received names: the stemlet, or **caulicle**; the seed-leaf, or **cotyledon** (usually 1 or 2); the bud, or **plumule**, lying between or above the cotyledons. These parts are well



FIG. 15. — PARTS OF THE BEAN.

R, cotyledon; O, caulicle; A, plumule; F, first node.

seen in the common bean (Fig. 15), particularly when the seed has been soaked for a few hours. One of the large cotyledons — comprising half of the bean — is shown at R. The caulicle is at O. The plumule is shown at A. The cotyledons are attached to the caulicle at F: *this point may be taken*

as the first node or joint.

The Number of Seed-leaves. — All plants having *two seed-leaves* belong to the group called **dicotyledons**. Such seeds in many cases split readily in halves, *e.g.* a bean. Some plants have only *one* seed-leaf in a seed. They form a group of plants called **monocotyledons**. Indian corn is an example of a plant with only one seed-leaf: a grain of corn does not split into halves as a bean does. Seeds of the pine family contain more than two cotyledons, but for our purposes they may be associated with the dicotyledons, although really forming a different group.

These two groups — the dicotyledons and the monocotyledons — represent two great natural divisions of the vegetable kingdom. The dicotyledons contain the woody

bark-bearing trees and bushes (except conifers), and most of the herbs of temperate climates except the grasses, sedges, rushes, lily tribes, and orchids. The flower-parts are usually in fives or multiples of five, the leaves mostly netted-veined, the bark or rind distinct, and the stem often bearing a pith at the centre. The monocotyledons usually have the flower-parts in threes or multiples of three, the leaves long and parallel-veined, the bark not separable, and the stem without a central pith.

Every seed is *provided with food* to support the germinating plant. Commonly this food is starch. The food may be stored *in the cotyledons*, as in bean, pea, squash; or *outside the cotyledons*, as in pine, and Indian corn. When the food is outside or around the embryo, it is usually called **endosperm**.

Seed-coats; Markings on Seed. — The embryo and endosperm are inclosed within a covering made of two or more layers and known as the **seed-coats**.

Over the point of the caulicle is a minute hole or a thin place in the coats known as the **micropyle**. This is the point at which the pollen-tube entered the forming ovule and through which the caulicle breaks in



FIG. 16. — EXTERNAL PARTS OF BEAN.

germination. The micropyle is shown at *M* in Fig. 16. The scar where the seed broke from its funiculus (or stalk that attached it to its pod) is named the **hilum**. It occupies a third of the length of the bean in Fig. 16. The hilum and micropyle are always present in seeds, but they are not always close together. In many cases it is difficult to identify the micropyle in the dormant seed, but its location is at once shown by the protruding caulicle as germination begins. Opposite the micropyle in the bean (at the other end of the hilum) is an elevation known as the **raphe**.

This is formed by a union of the funiculus, or seed-stalk, with the seed-coats, and through it food was transferred for the development of the seed, but it is now functionless.

Seeds differ wonderfully in size, shape, color, and other characteristics. They also vary in longevity. These characteristics are *peculiar to the species or kind*. Some seeds maintain life only a few weeks or even days, whereas others will "keep" for ten or twenty years. In special cases, seeds have retained vitality longer than this limit, but the stories that live seeds, several thousand years old, have been taken from the wrappings of mummies are unfounded.

Germination. — The embryo is not dead ; it is only dormant. *When supplied with moisture, warmth, and oxygen (air), it awakes and grows: this growth is germination.* The embryo lives for a time on the stored food, but gradually the plantlet secures a foothold in the soil and gathers food for itself. *When the plantlet is finally able to shift for itself, germination is complete.*

Early Stages of Seedling. — The germinating seed first *absorbs water, and swells*. The starchy matters gradually become soluble. The seed-coats are ruptured, the caulicle and plumule emerge. During this process the seed *respires freely, throwing off carbon dioxide (CO₂)*.

The caulicle usually elongates, and from its lower end roots are emitted. The elongating caulicle is known as the **hypocotyl** ("below the cotyledons"). That is, the hypocotyl is that part of the stem of the plantlet lying between the roots and the cotyledon. *The general direction of the young hypocotyl, or emerging caulicle, is downwards.* As soon as roots form, it becomes fixed and its subsequent growth tends to raise the cotyledons above the ground, as in the bean. When cotyledons rise into the

air, germination is said to be **epigeal** ("above the earth"). Bean and pumpkin are examples. When the hypocotyl does not elongate greatly and the cotyledons remain under ground, the germination is **hypogeal** ("beneath the earth"). Pea and scarlet runner bean are examples (Fig. 48). When the germinating seed lies on a hard surface, as on closely compacted soil, the hypocotyl and rootlets may not be able to secure a foothold and they assume grotesque forms. (Fig. 17.) Try this with peas and beans.

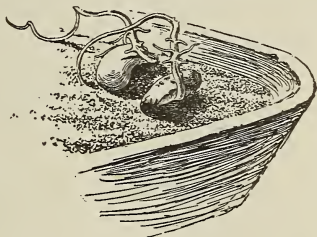


FIG. 17. — PEA. Grotesque forms assumed when the roots cannot gain entrance to the soil.

The first internode ("between nodes") above the cotyledons is the **epicotyl**. It elevates the plumule into the air, and *the plumule-leaves expand into the first true leaves of the plant*. These first true leaves, however, may be very unlike the later leaves in shape.

Germination of Bean. — The common bean, as we have seen (Fig. 15), has cotyledons that occupy all the space inside the seed-coats. When the hypocotyl, or elongated caulicle, emerges, the plumule-leaves have begun to enlarge, and to unfold (Fig. 18). The hypocotyl elongates rapidly. One end of it is held by the roots. The other is held by the seed-coats in the soil.



FIG. 18. — COTYLEDONS OF GERMINATING BEAN SPREAD APART TO SHOW ELONGATING CAULICLE AND PLUMULE.

It therefore takes the form of a loop, and the central part of the loop "comes up" first (*a*, Fig. 19). Presently the cotyledons come out of the seed-coats,



FIG. 19. — GERMINATION OF BEAN.

and the plant straightens and the cotyledons expand. These cotyledons, or “halves of the bean,” persist for some time (*b*, Fig. 19). They often become green and probably perform some function of foliage. Because of its large size, the Lima bean shows all these parts well.

Germination of Castor Bean. —

In the castor bean the hilum

and micropyle are at the smaller end (Fig. 20). The bean “comes up” with a loop, which indicates that the hypocotyl greatly elongates. On examining germinating seed, however, it will be found that the cotyledons are contained inside a fleshy body, or sac (*a*, Fig. 21). This sac is the endosperm. Against its inner surface the thin, veiny cotyledons are very closely pressed, ab-



FIG. 20. — SPROUTING OF CASTOR BEAN.



FIG. 21. — GERMINATION OF CASTOR BEAN.

Endosperm at *a*.



FIG. 22. — CASTOR BEAN.

Endosperm at *a*, *a*; cotyledons at *b*.



FIG. 23. — GERMINATION COMPLETE IN CASTOR BEAN.

sorbing its substance (Fig. 22). The cotyledons increase in size as they reach the air (Fig. 23), and become functional leaves.

Germination of Monocotyledons.—Thus far we have studied dicotyledonous seeds; we may now consider the monocotyledonous group. Soak kernels of corn. Note that the micropyle and hilum are at the smaller end (Fig. 24).

Make a longitudinal section through the narrow diameter; Fig. 25 shows it. The



FIG. 24.—SPROUTING INDIAN CORN.

Hilum at *h*; micropyle at *d*.



FIG. 25.—KERNEL OF INDIAN CORN.

Caulicle at *b*; cotyledon at *a*; plumule at *p*.

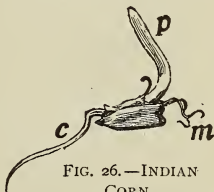


FIG. 26.—INDIAN CORN.

Caulicle at *c*; roots emerging at *m*; plumule at *p*.

single cotyledon is at *a*, the caulicle at *b*, the plumule at *p*. The cotyledon remains in the seed. The food is stored both in the cotyledon and as endosperm, chiefly the latter. The emerging shoot is the plumule, with a sheathing leaf (*p*, Fig. 26). The root is emitted from the tip of the caulicle, *c*. The caulicle is held in a sheath (formed mostly from the seed-coats), and some of the roots escape through the upper end of this sheath (*m*, Fig. 26). The epicotyl elongates, particularly if

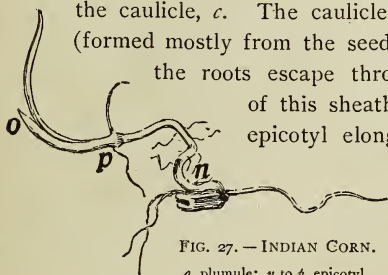


FIG. 27.—INDIAN CORN.
o, plumule; *n* to *p*, epicotyl.

the seed is planted deep or if it is kept for a time confined. In Fig. 27 the epicotyl has elongated from *n* to *p*. The true plumule-leaf is at *o*, but other leaves grow from its sheath. In Fig. 28 the roots are seen emerging from the two ends of the caulicle.

sheath, *c*, *m*; the epicotyl has grown to *p*; the first plumule-leaf is at *o*.

In studying corn or other fruits or seeds, the pupil should note how the seeds are arranged, as on the cob. Count the

rows on a corn cob. Odd or even in number? Always the same number? The silk is the style: find where it was attached to the kernel. Did the ear have any coverings? Explain. Describe colors and markings of kernels of corn; and of peas, beans, castor bean.

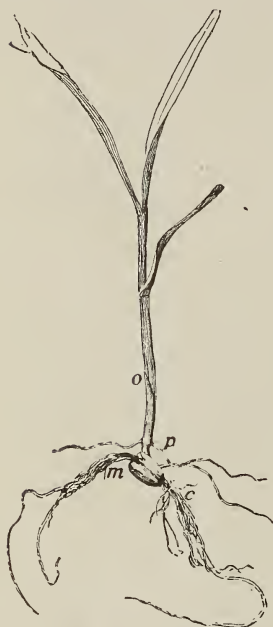


FIG. 28. — GERMINATION IS COMPLETE.

p, top of epicotyl; *o*, plumule-leaf;
m, roots; *c*, lower roots.

✓ **Gymnosperms.** — The seeds in the spruce cone, not being inclosed in a seed-vessel, readily fall out when the cone dries and the scales separate. Hence it is difficult to find cones with seeds in them after autumn has passed (Fig. 29). The tamarack is also a gymnosperm.

Remove a scale from a spruce cone and draw it and the seeds as they lie in place on the upper side of the scale.

Examine the seed, preferably with a magnifying glass. Is there a hilum? The micropyle is at the bottom or little end of the seed. Toss a seed upwards into the air. Why does it fall so slowly? Can you explain the peculiar whirling motion by the shape of the wing? Repeat the ex-

periment in the wind. Remove the wing from a seed and toss it and an uninjured seed into the air together. What do you infer from these experiments?

SUGGESTIONS.—Few subjects connected with the study of plant-life are so useful in schoolroom demonstrations as germination. The pupil should prepare the soil, plant the seeds, water them, and care for the plants.

1. Plant seeds in pots or shallow boxes. The box should not be very wide or long, and not over four inches deep; holes may be bored in the bottom so that it will not hold water. Plant a number of squash, bean, corn, spruce, or other seeds about an inch deep in damp sand or pine sawdust in this box. The depth of planting should be two to four times the diameter of the seeds. Keep the sand or sawdust moist but not wet. If the class is large, use several boxes, that the supply of specimens may be ample. Cigar boxes and chalk boxes are excellent for individual pupils. It is well to begin the planting of seeds at least ten days in advance of the lesson, and to make four or five different plantings at intervals. A day or two before the study is taken up, put seeds to soak in moss or cloth. The pupil then has a series from swollen seeds to complete germination, and all the steps can be made out. Dry seeds should be had for comparison. If there is no special room for laboratory, nor duplicate apparatus for every pupil, each experiment may be assigned to a committee of two pupils to watch in the schoolroom.

2. Good seeds for study are those detailed in the lesson, and sunflower, pumpkin, morning-glory, oats, wheat. It is best to use familiar seeds of farm and garden. Make drawings and notes of all the events in the germination. Note the effects of unusual conditions, as planting too deep and too shallow and different

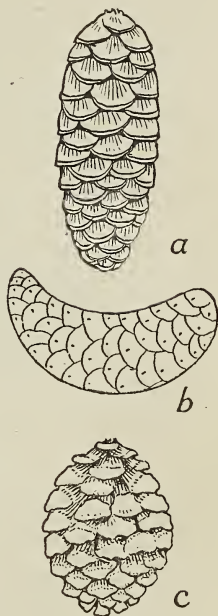


FIG. 29.—CONES OF *a*. white spruce; *b*. Jack pine; *c*. black spruce.

sides up. For hypogeal germination, use the garden pea or scarlet runner. Squash seeds are excellent for germination studies, because the cotyledons become green and leafy and germination is rapid. The castor bean may be bought at any seed store, and no more familiar seed, having endosperm, is available. In order to study the root development of germinating plantlets, it is well to provide a deeper box with a sloping glass side against which the seeds are planted (Fig. 29, A).

To show the effect of planting at various depths a box with glass sides and marked off in inches is convenient (Fig. 29, B).

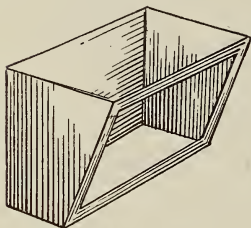


FIG. 29, A

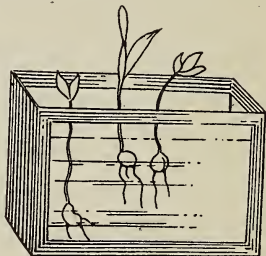


FIG. 29, B

3. Observe the germination of any common seed about the house premises. When elms or maples are abundant, the germination of their seeds may be studied in lawns and along fences.

4. When studying germination, the pupil should note the differences in shape and size between cotyledons and plumule-leaves, and between plumule-leaves and the normal leaves (Fig. 30). Make drawings.

5. The presence of starch may be detected by applying diluted tincture of iodine to the part to be tested. If a bluish or purplish-black color appears, starch is present. Test all available seeds for starch.



FIG. 30. — MUSKMELON SEEDLINGS, with the unlike seed-leaves and true leaves.

Record your results by arranging the seeds in three classes, 1. Much starch (color blackish or purple), 2. Little starch (pale-blue or greenish), 3. No starch (brown or yellow).

6. *Rate of growth of seedlings as affected by differences in temperature.* Germinate seeds in different temperature and record results.

7. *Is air necessary for the germination and growth of seedlings?* Germinate seeds in a bottle with a tight cork. Compare with others grown in air.

8. *What is the nature of the gas given off by germinating seeds?* Fill a tin box or large-necked bottle with dry beans or peas, then add water; note how much they swell. Secure two fruit-jars. Fill one of them a third full of beans and keep them moist. Allow the other to remain empty. In a day or two insert a lighted splinter or taper into each. In the empty jar the taper burns: it contains oxygen. In the seed jar the taper goes out: the air has been replaced by carbon dioxide. The air in the bottle may be tested for carbon dioxide by removing some of it with a rubber bulb attached to a glass tube (or a fountain-pen filler) and bubbling it through lime-water.

9. *Temperature.* Usually there is a perceptible rise in temperature in a mass of germinating seeds. This rise may be tested with a thermometer.

10. *Interior of seeds.* Soak seeds for twenty-four hours and remove the coat. Distinguish the embryo from the endosperm. Test with iodine.

11. *Of what utility is the food in seeds?* Soak some grains of corn overnight and remove the endosperm, being careful not to injure the fleshy cotyledon. Plant the incomplete and also some complete grains in moist sawdust and measure their growth at intervals. (Boiling the sawdust will destroy molds and bacteria which might interfere with experiment.) Peas or beans may be sprouted on damp blotting-paper; the cotyledons of one may be removed, and this with a normal seed equally advanced in germination may be placed on a perforated cork floating in water in a jar so that the roots extend into the water. Their growth may be observed for several weeks.

12. *Effect of darkness on seeds and seedlings.* Grow seedlings in the dark and compare with those grown in the light.

13. *Seed-testing.* It is important that one know before planting whether seeds are good, or able to grow. A simple seed-tester may be made of two plates, one inverted over the other (Fig. 31). The lower plate is nearly filled with clean sand, which is covered with cheese cloth or blotting paper on which the seeds are placed. Canton flannel is sometimes used in place of sand and blotting

paper. The seeds are then covered with another blotter or piece of cloth, and water is applied until the sand and papers are saturated. Cover with the second plate.

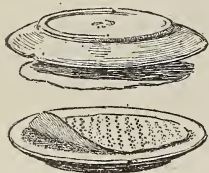


FIG. 31. — A HOME-MADE SEED-TESTER.

Set the plates where they will have about the temperature that the given seeds would require out of doors, or perhaps a slightly higher temperature. Place 100 or more grains of clover, corn, wheat, oats, or other seeds in the tester, and keep record of the number that sprout. The result will give a percentage measure of the ability of the seeds to grow. Note whether all the seeds sprout with equal vigor and rapidity. Most seeds will

sprout in a week or less. Usually such a tester must have fresh sand and paper after every test, for mold fungi are likely to breed in it. If cotton flannel is used, it may be boiled. If possible, the seeds should not touch each other.

NOTE TO TEACHER. — With the study of germination, the pupil will need to begin dissecting.

For dissecting, one needs a lens for the examination of the smaller parts of plants and animals. It is best to have the lens mounted on a frame, so that the pupil has both hands free for pulling the part in pieces. An ordinary pocket lens may be mounted on a wire in a block, as in Fig. A. A cork is slipped on the top of the wire to avoid injury to the face. The pupil should be provided with two dissecting needles (Fig. B), made by securing an ordinary needle in a pencil-like stick. Another convenient arrangement is shown in Fig. C. A small tin dish is used for the base. Into this a stiff wire standard is soldered. The dish is filled with solder, to make it heavy and firm. Into a cork slipped on the standard, a cross wire is inserted, holding on the end a jeweller's glass. The lens can be moved up and down and sidewise. This outfit can be made for about seventy-five cents. Fig. D shows a convenient hand-rest or dissecting-stand to be used under this lens. It may be 16 in. long, 4 in. high, and 4 or 5 in. broad.

The hands rest on the sloping surfaces, while the specimen lies on the horizontal plane.

Various kinds of dissecting microscopes are on the market, and these are to be recommended when they can be afforded.

Instructions for the use of the compound microscope, with which some schools may be equipped, cannot be given in a brief

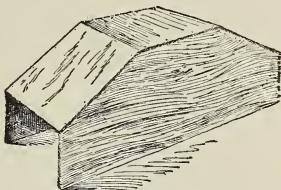
space ; the technique requires careful training. Such microscopes are not needed unless the pupil studies cells and tissues.



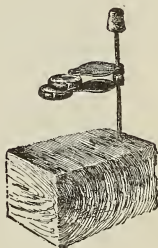
B. — DIS-
SECTING
NEEDLE
 $\frac{1}{2}$ natural
size.



C. — DISSECTING GLASS.



D. — DISSECTING STAND.



A. — IMPROVED
STAND FOR LENS.

CHAPTER VII

THE ROOT—THE FORMS OF ROOTS

The Root System. — The offices of the root are *to hold the plant in place*, and *to gather food*. Not all the food materials, however, are gathered by the roots.



FIG. 32. — TAP-ROOT SYSTEM OF ALFALFA.



FIG. 33. — TAP-ROOT OF THE DANDELION.

The entire mass of roots of any plant is called its **root system**. The root system may be annual, biennial or perennial, herbaceous or woody, deep or shallow, large or small.

Kinds of Roots. — A strong leading central root, which runs directly downwards, is a tap-root. The tap-root forms

an axis from which the side roots may branch. The side or spreading roots are usually smaller. Plants that have such a root system are said to be *tap-rooted*. Examples are red clover, alfalfa, beet, turnip, radish, burdock, dandelion (Figs. 32, 33).

A **fibrous root** system is one that is composed of many, nearly equal, slender branches. The greater number of plants have fibrous roots. Examples are many common grasses, wheat, oats, corn. The buttercup in Fig. 34 has a fibrous root system. Many trees have a strong tap-root when very young, but after a while it ceases to extend strongly and the side roots develop, until finally the tap-root character disappears.



FIG. 34.—A BUTTERCUP PLANT, with fibrous roots.

Shape and Extent of the Root System.—The depth to which roots extend depends on the *kind of plant*, and the *nature of the soil*. Of most plants the roots extend far *in all directions* and lie comparatively *near the surface*. The roots usually radiate from a common point just beneath the surface of the ground.

The roots grow here and there in search of food, often extending much farther in all directions than the spread of the top of the plant. Roots tend to spread farther in poor soil than in rich soil, for the same size of plant. *The root has no such definite form as the stem has*. Roots are usually very crooked, because they are constantly turned aside by obstacles. Examine roots in stony soil.

The extent of root surface is usually very large, for the feeding roots are fine and very numerous. An ordinary plant of Indian corn may have a total length of root (measured as if the roots were placed end to end) of several hundred feet.

The fine feeding roots are *most abundant in the richest part of the soil*. They are attracted by the food materials. Roots often will completely surround a bone or other morsel. When roots of trees are exposed, observe that most of them are horizontal and lie near the top of the ground. Some roots, as of willows, extend far *in search of water*. They often run into wells and drains, and into the margins of creeks and ponds. Grow plants in a long narrow box, in one end of which the soil is kept very dry and in the other moist: observe where the roots grow.

Buttresses. — With the increase in diameter, the upper roots often protrude above the ground and become *bracing buttresses*. These buttresses are usually largest in trees



FIG. 35. — THE BRACING BASE OF A TREE GROWING IN EXPOSED PLACE.

which always have been exposed to strong winds (Fig. 35). Because of growth and thickening, the roots elevate part of their diameter, and this with the washing away of the soil makes them appear as if they had risen out of the ground.

Aërial Roots. — Although roots usually grow underground, *there are some that naturally grow above ground*. These usually occur on climbing plants, the roots becoming *supports* or fulfilling the office of tendrils. These aërial roots *usually turn away from the light*, and therefore enter the

crevices and dark places of the wall or tree over which the plant climbs. The trumpet creeper (Fig. 36) and true or English ivy climb by means of roots.

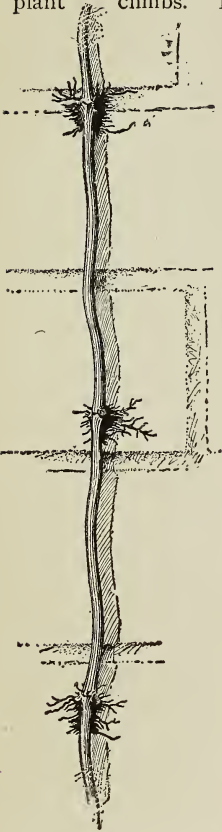


FIG. 36.—AËRIAL ROOTS OF TRUMPET CREEPER OR TECOMA.



FIG. 37.—AËRIAL ROOTS OF AN ORCHID.

In some plants all the roots are aërial; that is, *the plant grows above ground*, and the roots gather food from the air. Such plants usually grow on trees. They are known as *epiphytes* or *air-plants*. The most familiar examples are some of the tropical orchids, which are grown in glass-houses (Fig. 37). Rootlike organs of dodder and other parasites are discussed in a later chapter.

Some plants bear aërial roots, that may *propagate the plant* or may *act as braces*. They are often called **prop-roots**. The roots of Indian corn are familiar (Fig. 38). Many ficus trees, as the banyan of India, send out roots from their branches; when these roots reach the ground they take hold and become great trunks, thus spreading the



FIG. 38. — INDIAN CORN, showing the brace roots at oo.

top of the parent tree over large areas. The muscadine grape of the Southern states often sends down roots from its stems. The mangrove tree of the tropics grows along seashores and sends down roots from the overhanging branches (and from the fruits) into the shallow water, and thereby gradually marches into the sea. The tangled mass behind catches the drift, and soil is formed.

Adventitious Roots. — Sometimes roots grow from the stem or other unusual places as the result of some accident to the plant, being located without known method or law. They are called **adventitious** (chance) **roots**. Cuttings of the stems of willows, virginia creeper, geraniums, and other plants, when planted, send out adventitious roots and form new plants. The ordinary roots, or soil roots, are of course not classed as adventitious roots. The adventitious roots arise on occasion, and not as a normal or regular course in the growth of the plant.

No two roots are alike; that is, they vary among themselves as stems and leaves do. *Each kind of plant has its*

own form or habit of root (Fig. 39). Carefully wash away the soil from the roots of any two related plants, as oats and wheat, and note the differences in size, depth, direction, mode of branching, number of fibrils, color, and other

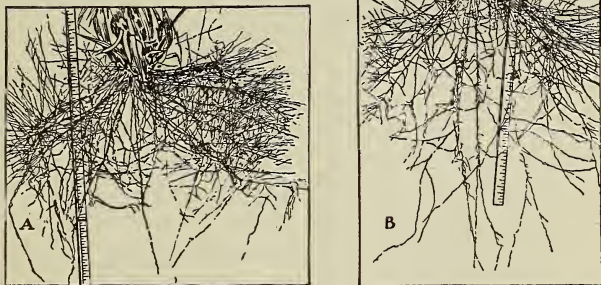


FIG. 39.—ROOTS OF BARLEY AT A AND CORN AT B.
Carefully trace the differences.

features. The character of the root system often governs the treatment that the farmer should give the soil in which the plant or crop grows.

Roots differ not only in their form and habit, but also in color of tissue, character of bark or rind, and other features. It is excellent practice to *try to identify different plants by means of their roots*. Let each pupil bring to school two plants with the roots very carefully dug up, as corn, potato, bean, wheat, pumpkin, clover, sweet pea, raspberry, strawberry, or other common plants.

Root Systems of Weeds.—Some weeds are pestiferous because they seed abundantly, and others because their underground parts run deep or far and are persistent. Make out the root systems in the six most injurious weeds in your locality.

CHAPTER VIII

THE ROOT. — FUNCTION AND STRUCTURE

The function of roots is twofold, — to provide *support or anchorage* for the plant, and to *collect and convey food materials*. The first function is considered in Chapter VII; we may now give attention in more detail to the second.



FIG. 40. — WHEAT GROWING UNDER DIFFERENT SOIL TREATMENTS. Soil deficient in nitrogen; commercial nitrogen applied to pot 3 (on right).

The feeding surface of the roots is *near their ends*. As the roots become old and hard, they serve only as *channels through which food passes* and as *hold-fasts or supports* for the plant. The root-hold of a plant is very strong. Slowly pull upwards on some plant, and note how firmly it is anchored in the soil.

Roots have power to choose their food; that is, they do not absorb all substances with which they come in contact. They do not take up great quantities of useless or harmful materials, even though these materials may be abundant in the soil; but they may take up a greater quantity of some of the plant-foods than the plant can use to advantage. *Plants respond very quickly to liberal feeding*, — that is, to the application of plant-food to the soil (Fig 40). The poorer the soil, the more marked are the results, as a rule, of the application

of fertilizers. Certain substances, as common salt, will kill the roots.

Roots absorb Substances only in Solution.—Substances cannot be taken in solid particles. These materials are in solution in the soil water, and the roots themselves also have the power to dissolve the soil materials to some extent by means of substances that they excrete. The materials that come into the plant through the roots are *water and mostly the mineral substances*, as compounds of potassium, iron, phosphorus, calcium, magnesium, sulphur, and chlorine. These mineral substances compose the ash when the plant is burned. The carbon is derived from the air through the green parts. Oxygen is derived from the air and the soil water.

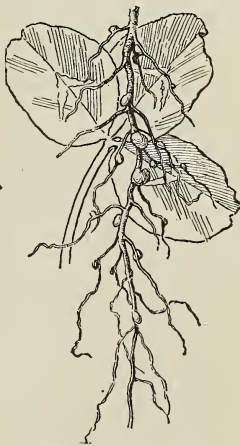


FIG. 41.—NODULES ON ROOTS OF RED CLOVER.

Nitrogen enters through the Roots.

—All plants must have nitrogen; yet, although about four fifths of the air is nitrogen, plants are not able, so far as we know, to take it in through their leaves. It enters through the roots in combination with other elements, chiefly in the form of nitrates (certain combinations with oxygen and a mineral base). The great family of leguminous plants, however (as peas, beans, clover, alfalfa, vetch), *use the nitrogen contained in the air in the soil*. They are able to utilize it through the *agency of nodules* on their roots (Figs. 41, 42). These nodules contain bacteria, which appropriate the free or uncombined nitrogen and pass it on to the plant. The nitrogen

becomes incorporated in the plant tissue, so that these crops are high in their nitrogen content. Inasmuch as



FIG. 42.—NODULES ON VETCH.

nitrogen in any form is expensive to purchase in fertilizers, the use of leguminous crops to plow under is a very important agricultural practice in preparing the land for other crops. In order that leguminous crops may acquire atmospheric nitrogen more freely and thereby thrive better, *the land is sometimes sown or inoculated with the nodule-forming bacteria.*

Roots require moisture in order to serve the plant. The soil water that is valuable to the plant is not the free water, but the *thin film of moisture which adheres to each little particle of soil.* The finer the soil, the greater the number of particles, and therefore the greater is the quantity of film moisture that it can hold. This moisture surrounding the grains may not be perceptible, yet the plant can use it. *Root absorption may continue in a soil which seems to be dust dry.* Soils that are very hard and



FIG. 43.—TWO KINDS OF SOIL THAT HAVE BEEN WET AND THEN DRIED. The loamy soil above remains loose and capable of growing plants; the clay soil below has baked and cracked.

“baked” (Fig. 43) contain very little moisture or air,—not so much as similar soils that are granular or mellow.

Proper Temperature for Root Action. — *The root must be warm in order to perform its functions.* Should the soil of fields or greenhouses be much colder than the air, the plant suffers. When in a warm atmosphere, or in a dry atmosphere, plants need to absorb much water from the soil, and the roots must be warm if the root-hairs are to supply the water as rapidly as it is needed. *If the roots are chilled, the plant may wilt or die.*

Roots need Air. — Corn on land that has been flooded by heavy rains loses its green color and turns yellow. *Besides diluting plant-food, the water drives the air from the soil, and this suffocation of the roots is very soon apparent in the general ill health of the plant.* Stirring or tilling the soil aerates it. Water plants and bog plants have adapted themselves to their particular conditions. They get their air either by special surface roots, or from the water through stems and leaves.

Rootlets. — *Roots divide into the thinnest and finest fibrils: there are roots and there are rootlets.* The smallest rootlets are so slender and delicate that they break off even when the plant is very carefully lifted from the soil.

The rootlets, or fine divisions, are clothed with the root-hairs (Figs. 44, 45, 46). These root-hairs attach to the soil particles, and a great amount of soil is thus brought into actual contact with the plant. These are very delicate, prolonged, surface cells of the roots. They are borne for a short distance just back of the tip of the root.

Rootlet and root-hair differ. The rootlet is a compact



FIG. 44. — ROOT-HAIRS OF THE RADISH.

cellular structure. The root-hair is a delicate tubular cell (Fig. 45), within which is contained living matter (protoplasm); and the protoplasmic lining membrane of the

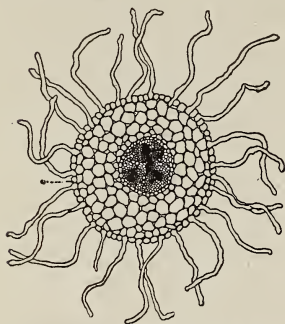


FIG. 45. — CROSS-SECTION OF ROOT, enlarged, showing root-hairs.

wall governs the entrance of water and substances in solution. Being long and tube-like, these root-hairs are especially adapted for taking in the largest quantity of solutions; and they are the principal means by which plant-food is absorbed from the soil, although the surfaces of the rootlets themselves do their part. > Water plants do not produce an

abundant system of root-hairs, and such plants depend largely on their rootlets.

The root-hairs are very small, often invisible. They, with the young roots, are usually broken off when the plant is pulled up. They are best seen when seeds are germinated between layers of dark blotting-paper or flannel. On the young roots, they will be seen as a mold-like or gossamer-like covering. *Root-hairs soon die*: they do not grow into roots. New ones form as the root grows.

Osmosis.—The water with its nourishment goes through the thin walls of the root-hairs and rootlets by the process of osmosis. If there are two liquids of different density



FIG. 46. — ROOT-HAIR, much enlarged, in contact with the soil particles (*s*). Air-spaces at *a*; water-films on the particles, as at *w*.

on the inside and outside of an organic (either vegetable or animal) membrane, the liquids tend to mix through the membrane. ◁ The *law of osmosis* is that *the most rapid flow is towards the denser solution* ▷ The protoplasmic lining of the cell wall is such a membrane. The soil water being a weaker solution than the sap in the roots, the flow is into the root. A strong fertilizer sometimes causes a plant to wither, or “burns it.” Explain.

Kinds of Roots. — The root that grows from the lower end of the caulicle is the *first* or primary root. Secondary roots branch from the primary root. Branches of secondary roots are sometimes called tertiary roots.

Internal Structure of Roots. — A section of a root shows that it consists of a *central cylinder* (see Fig. 45) surrounded by a layer. This layer is called the cortex. The outer layer of cells in the cortex is called the epidermis, and some of the cells of the epidermis are prolonged and form the delicate root-hairs. The cortex resembles the bark of the stem in its nature. The central cylinder contains many tube-like canals, or “vessels” that convey water and food (Fig. 45). Cut a sweet potato across (also a radish and a turnip) and distinguish the central cylinder, cortex, and epidermis. Notice the hard cap on the tip of roots. Roots differ from stems in having no real pith. Do the secondary roots grow from the cortex, or from the central cylinder of the primary root? Trim or peel the cortex from a root and its branches and determine whether the branches still hold to the central cylinder of the main root.

Microscopic Structure of Roots. — Near the end of any young root or shoot the cells are found to differ from each other more or less, according to the distance from the point. *This differentiation takes place in the region just back of the growing point.* To study growing points, use

the hypocotyl of Indian corn which has grown about one half inch. Make a longitudinal section. Note these points (Fig. 47): (*a*) the tapering root-cap beyond the growing point; (*b*) the blunt end of the root proper and the rectangular shape of the cells found there; (*c*) the group of cells in the middle of the first layers beneath the root-

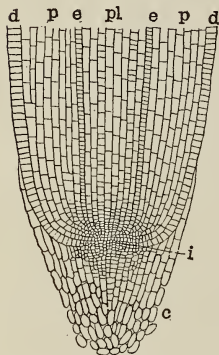


FIG. 47. — GROWING POINT OF ROOT OF INDIAN CORN.

d, d, cells which will form the epidermis; *p, p*, cells that will form bark; *e, e*, endodermis; *pl*, cells which will form the axis cylinder; *i*, initial group of cells, or growing point proper; *c*, root-cap.

cap,—this group is the growing point; (*d*) study the slight differences in the tissues a short distance back of the growing point. There are four regions: the **central cylinder**, made up of several rows of cells in the centre (*pl*); the **endodermis**, (*e*) composed of a single layer on each side which separates the central cylinder from the bark; the **cortex**, or inner bark, (*e*) of several layers outside the endodermis; and the **epidermis**, or outer layer of bark on the outer edges (*d*). Make a drawing of the section. If a series of the cross-sections of the hypocotyl should be made and studied, beginning near the growing point and going upwards, it would

be found that these four tissues become more distinctly marked, for at the tip the tissues have not yet assumed their characteristic form. The central cylinder contains the ducts and vessels which convey the sap.

The Root-cap. — Note the form of the root-cap shown in the microscopic section drawn in Fig. 47. Growing cells, and especially those which are forming tissue by subdividing, are very delicate and are easily injured. The

cells forming the root-cap are older and tougher and are suited for pushing aside the soil that the root may penetrate it.

Region of most Rapid Growth.—The roots of a seedling bean may be marked at equal distances by waterproof ink or by bits of black thread tied moderately tight. The seedling is then replanted and left undisturbed for two days.

When it is dug up, the region of most rapid growth in the root can be deter-

mined. Give a reason why *a root cannot elongate throughout its length*, — whether there is anything to prevent a young root from doing so.

In Fig. 48 is shown a germinating scarlet runner bean with a short root upon which are marks made with waterproof ink; and the same root (Fig. 49) is shown after it has grown longer. Which part of it did not lengthen at all? Which part lengthened slightly? Where is the region of most rapid growth?

Geotropism.—Roots turn towards the earth, even if the seed is planted with the micropyle up. This phenomenon is called **positive geotropism**. Stems grow away from the earth. This is **negative geotropism**.

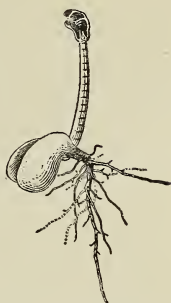


FIG. 48.—THE MARKING OF THE STEM AND ROOT.

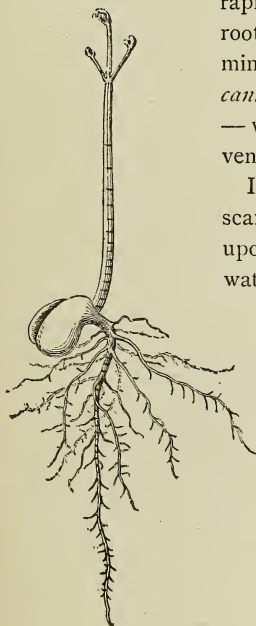


FIG. 49.—THE RESULT.

SUGGESTIONS (Chaps. VII and VIII). — 1. *Tests for food.* Examine a number of roots, including several fleshy roots, for the presence of food material, making the tests used on seeds.

2. *Study of root-hairs.* Carefully germinate radish, turnip, cabbage, or other seed, so that no delicate parts of the root will be injured. For this purpose, place a few seeds in packing-moss or in the folds of thick cloth or of blotting-paper, being careful to keep them moist and warm. In a few days the seed has germinated, and the root has grown an inch or two long. Notice that, except at a distance of about a quarter of an inch behind the tip, the root is covered with minute hairs (Fig. 44). They are actually hairs; that is, root-hairs. Touch them and they collapse, they are so delicate. Dip one of the plants in water, and when removed the hairs are not to be seen. The water mats them together along the root and they are no longer evident. Root-hairs are usually destroyed when a plant is pulled out of the soil, be it done ever so carefully. They cling to the minute particles of soil (Fig. 46). The hairs show best against a dark background.

3. On some of the blotting-papers, sprinkle sand; observe how the root-hairs cling to the grains. Observe how they are flattened when they come in contact with grains of sand.

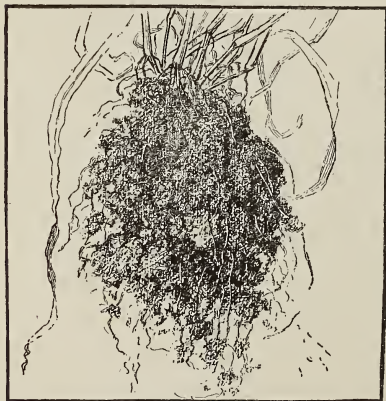


FIG. 50. — THE GRASP OF A PLANT ON THE PARTICLES OF EARTH. A grass plant pulled in a garden.

4. *Root hold of plant.* The pupil should also study the root hold. Let him carefully pull up a plant. If a plant grow alongside a fence or other rigid object, he may test the root hold by securing a string to the plant, letting the string hang over the fence, and then adding weights to the string. Will a stake of similar size to the plant and extending no deeper in the

ground have such firm hold on the soil? What holds the ball of earth in Fig. 50?

5. *Roots exert pressure.* Place a strong bulb of hyacinth or daffodil on firm-packed earth in a pot ; cover the bulb nearly to the top with loose earth ; place in a cool cellar ; after some days or weeks, note that the bulb has been raised out of the earth by the forming roots. All roots exert pressure on the soil as they grow. Explain.

6. *Response of roots and stems to the force of gravity, or geotropism.* Plant a fast-growing seedling in a pot so that the plumule extends through the drain hole and suspend the pot with mouth up (*i.e.* in the usual position). Or use a pot in which a plant is already growing, cover with cloth or wire gauze to prevent the soil from falling, and suspend the pot in an inverted position (Fig. 51). Notice the behavior of the stem, and after a few days remove the soil and observe the position of the root. If a pot is laid on one side, and changed every two days and laid on its opposite side, the effect on the root and stem will be interesting. If a fleshy root is planted wrong end up, what is the result? Try it with pieces of horse-radish root. By planting radishes on a slowly revolving wheel the effect of gravity may be neutralized.



FIG. 51.—
PLANT GROW-
ING IN IN-
VERTED POT.

7. *Region of root most sensitive to gravity.* Lay on its side a pot containing a growing plant. After it has grown a few days, wash away the earth surrounding the roots. Which turned downwards most decidedly, the tip of root or the upper part ?

8. *Soil texture.* Carefully turn up soil in a rich garden or field so that you have unbroken lumps as large as a hen's egg.

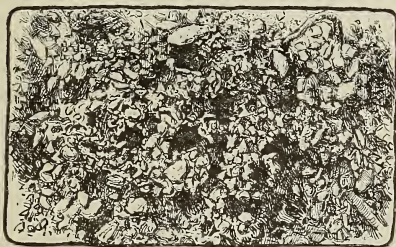


FIG. 52.—HOLES IN SOIL MADE BY ROOTS, now decayed. Somewhat magnified.

Then break these lumps apart carefully with the fingers and determine whether there are any traces or remains of roots (Fig. 52). Are there any pores, holes, or channels made by roots? Are the roots in them still living? Compare another lump from a clay bank or pile

where no plants have been growing. Is there any difference in

texture? Grind up this clay lump very fine, put it in a saucer, cover with water, and set in the sun. After a time it will have the appearance shown in the lower saucer in Fig. 43. Compare this with mellow garden-soil. In which will plants grow best, even if the plant-food were the same in both? Why?

9. *To test the effect of moisture on the plant*, let a plant in a pot or box dry out till it wilts; then add water and note the rapidity with which it recovers. Vary the experiment in quantity of water applied. Does the plant call for water sooner when it stands in a sunny window than when in a cool, shady place? Prove it. Immerse a potted plant above the rim of the pot in a pail of water and let it remain there. What is the consequence? Why?

10. *To test the effect of temperature on roots*. Put one pot in a dish of ice water, and another in a dish of warm water, and keep them in a warm room. In a short time notice how stiff and vigorous is the one whose roots are warm, whereas the other may show signs of wilting.

11. *The process of osmosis*. Chip away the shell from the large end of an egg so as to expose the uninjured membrane beneath for an area about as large as a ten-cent piece. With sealing-wax or paste stick a quill about three inches long to the smaller end of the egg. After the tube is in place, run a hat pin into it so as to pierce both shell and membrane; or use a short glass tube, first scraping the shell thin with a knife and then boring through it with the tube. Now set the egg upon the mouth of a pickle jar nearly full of water, so that the large end with the exposed membrane is beneath the waters. After several hours, observe the tube on top of the egg to see whether the water has forced its way into the egg and increased its volume, so that part of its contents are forced up into the tube. If no tube is at hand, see whether the contents are forced through the hole which has been made in the small end of the egg. Explain how the law of osmosis is verified by your result. If the eggshell contained only the membrane, would water rise into it? If there were no water in the bottle, would the egg-white pass down into the bottle?

12. *The region of most rapid growth*. The pupil should make marks with waterproof ink on any soft, growing roots. Place seeds of beans, radish, or cabbage between layers of blotting-paper or thick cloth. Keep them damp and warm. When stem and root have grown an inch and a half long each, with waterproof ink mark spaces exactly one quarter inch apart (Figs. 48, 49). Keep the plantlets moist for a day or two, and it will be found that on the stem some or all of the marks are more than one quarter inch apart; on the root the marks have not separated. The root has grown beyond the last mark.

CHAPTER IX

THE STEM—KINDS AND FORMS; PRUNING

The Stem System.—The stem of a plant is the part that *bears the buds, leaves, flowers, and fruits.* Its office is to *hold these parts up to the light and air*; and through its tissues the various food-materials and the life-giving fluids *are distributed to the growing and working parts.*

The entire mass or fabric of stems of any plant is called its **stem system**. It comprises the trunk, branches, and twigs, but not the stalks of leaves and flowers that die and fall away. The stem system may be herbaceous or woody, annual, biennial, or perennial; and it may assume many sizes and shapes.

Stems are of Many Forms.—The general way in which a plant grows is called its **habit**. The habit is the *appearance or general form*. Its habit may be open or loose, dense, straight, crooked, compact, straggling, climbing, erect, weak, strong, and the like. The roots and leaves are *the important functional or working parts*; the stem merely connects them, and its form is exceedingly variable.

Kinds of Stems.—*The stem may be so short as to be scarcely distinguishable.* In such cases the crown of the plant—that part just at the surface of the ground—bears the leaves and flowers; but this crown is really a very short stem. The dandelion, Fig. 33, is an example. Such plants are often said to be **stemless**, however, in order to distinguish them from plants that have long or conspic-

uous stems. *These so-called stemless plants die to the ground every year.*

Stems are **erect** when they grow straight up (Figs. 53, 54). They are **trailing** when they run along on the ground,



FIG. 53.—ERECT SIMPLE
STEM OF GRASS.



FIG. 54.—STRICT UPRIGHT STEM
OF NARROW-LEAVED DOCK.

as melon, wild morning-glory (Fig. 55). They are **creeping** when they run on the ground and take root at places,



FIG. 55.—TRAILING STEM OF WILD MORNING-GLORY.

as the strawberry. They are **decumbent** when they lop over to the ground. They are **ascending** when they lie mostly or in part on the ground, but stand more or less upright at their ends; example, a tomato. They are

climbing when they cling to other objects for support (Figs. 36, 56).

Trees in which the main trunk or the "leader" continues to grow from its tip are said to be **excurrent** in growth. *The branches are borne along the sides of the trunk, as in common pines (Fig. 57) and spruces.* Excurrent means *running out* or *running up*.

Trees in which the main trunk does not continue are said to be **deliquescent**. *The branches arise from one common point or from each other.* The stem is lost in the branches. The apple tree, plum (Fig. 58), maple, elm, and oak are familiar examples. Deliquescent means *dissolving* or *melting away*.

Each kind of plant has its own peculiar habit or direction of growth; spruces always grow to a single stem or trunk, pear



FIG. 56.—A
TWINING PLANT
(Hop).



FIG. 57.—EXCURRENT
TRUNK (Spruce).



FIG. 58.—DELIQUESCENT TRUNK
OF PLUM TREE.

trees are always deliquescent, morning-glories are always trailing or climbing, strawberries are always creeping. We do not know why each plant has its own habit, but the habit is in some way *associated with the plant's genealogy or with the way in which it has been obliged to live.*

The stem may be **simple** or **branched**. A simple stem usually grows from the terminal bud, and side branches either do not start, or, if they start, they soon perish. Grass stems (Fig. 53) are usually simple. So are palms.

Branched stems may be of very different habit and shape. Some stem systems are narrow and erect; these are said to be *strict* (Fig. 54). Others are *diffuse, open, branchy, twiggy.*

Nodes and Internodes.—The parts of the stem at which buds grow are called **nodes** or **joints** and the spaces between the buds are **internodes**. The stem at nodes is usually enlarged, and the pith is usually interrupted. The distance between the nodes is influenced by the vigor of the plant: how?



FIG. 59.—RHIZOME OR ROOTSTOCK.

Stems vs. Roots.—Roots sometimes grow above ground (Chap. VII); so, also, *stems sometimes grow underground*, and they are then known as **subterranean stems, rhizomes, or rootstocks** (Fig. 59).

Stems normally bear leaves and buds, and thereby are they distinguished from roots; usually, also, they contain a pith. The leaves, however, may be reduced to mere scales, and the buds beneath them may be scarcely visible.

Thus the "eyes" on a potato are cavities with a bud or buds at the bottom (Fig. 60). The potato tuber is a swollen underground stem, and the eyes mark the position where leaves and buds would appear, if the stem were in the sunlight.



FIG. 60. — SPROUTS ARISING FROM THE BUDS, or eyes, of a potato tuber.

How Stems elongate. — *Roots elongate by growing near the tip. Stems elongate by growing more or less throughout the young or soft part or "between joints" (Figs. 48, 49). But any part of the stem soon reaches a limit beyond which it cannot grow, or becomes "fixed"; and the new parts beyond elongate until they, too, become rigid. When a part of the stem once becomes fixed or hard, it never increases in length: that is, the trunk or woody parts never grow longer or higher; branches do not become farther apart or higher from the ground.*

Stems are modified in form by the particular or incidental conditions under which they grow. *The struggle for light* is the chief factor in determining the shape and direction of any limb (Chap. II). This is well illustrated in any tree or bush that grows against a building or on the margin of a forest (Fig. 4). In a very dense thicket the innermost trees shoot up over the others or they perish. Examine any stem and endeavor to determine why it took its particular form.

The stem is cylindrical, the outer part being bark and the inner part being wood or woody tissue. In the dicotyledonous plants, the bark is usually easily separated from the remainder of the cylinder at some time of the year; in monocotyledonous plants the bark is not free. Growth in thickness takes place inside the covering and not on the very

outside of the plant cylinder. It is evident, then, that the covering of *bark must expand in order to allow of the expansion of the woody cylinder within it.* The tis-

sues, therefore, must be under constant pressure or tension. It has been determined that the pressure within a growing trunk is often as much as fifty pounds to the square inch. The lower part of the limb in Fig. 61 shows that the outer layers of bark (which are long since dead, and serve only as protective tissue) have reached the limit of their expanding capacity and have begun to split. The pupil will now be interested in the bark on the body of an old elm tree (Fig. 62); and he should be able to suggest one reason why stems remain cylindrical, and why the old bark becomes marked with furrows, scales, and plates.



FIG. 61.—
CRACKING
OF THE
BARK ON AN
ELM
BRANCH.

Most woody plants increase in diameter by the addition of an *annual layer* or “ring” on the outside of the woody cylinder, underneath the bark. The monocotyledonous plants comprise very few trees and shrubs in temperate climates and none in our area (the palms are of this class); and they do not increase greatly in diameter and they rarely branch to any extent. Examine the woodpile for information as to the annual rings.

Bark-bound Trees.—If, for any reason, the bark should become so dense and strong that the trunk cannot expand, the tree is said to be “bark-bound.” Such condition is not rare in quick growing trees that have been neglected.

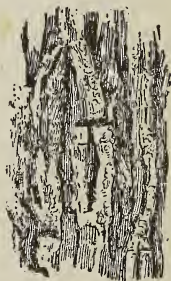


FIG. 62.—PIECE OF
BARK FROM AN
OLD ELM TRUNK.

When good tillage is given to such trees, they may not be able to overcome the rigidity of the old bark, and, therefore, do not respond to the treatment. Sometimes the thinner-barked parts may outgrow in diameter the trunk or the old branches below them. The remedy is to *release the tension*. This may be done either by softening the bark (by washes of soap or lye), or by separating it. The latter is done by slitting the bark-bound part (in spring), thrusting the point of a knife through the bark to the wood and then drawing the blade down the entire length of the bark-bound part. The slit is scarcely discernible at first, but it opens with the growth of the tree, filling up with new tissue beneath. Let the pupil consider the ridges which he now and then finds on trees, and determine whether they have any significance — whether the tree has ever been released or injured by natural agencies.

The Tissue covers the Wounds and "heals" them.

— This is seen in Fig. 63, in which a ring of tissue rolls out over the wound. This ring of healing tissue forms most rapidly and uniformly when the wound is smooth and regular. Observe the healing on broken and splintered limbs; also the difference in rapidity of healing between wounds on strong and weak limbs. There is difference in the rapidity of the healing process in different kinds of trees. Compare the poplar tree and the elm. This tissue may in

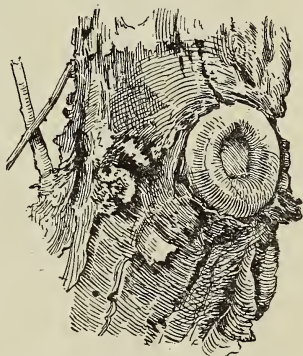


FIG. 63.—PROPER CUTTING OF A BRANCH. The wound will soon be "healed."

turn become bark-bound, and the healing may stop. On large wounds it progresses more rapidly the first few years than it does later. This roll or ring of tissue is called a **callus**.



FIG. 64. — ERRONEOUS PRUNING.

The callus grows from the living tissue of the stem just about the wound. It cannot cover long, dead stubs or very rough, broken branches (Fig. 64). Therefore, in pruning *the branches should be cut close to the trunk and made even and smooth; all long stubs must be avoided*. The seat of the wound should be close to the living part of the trunk, for the

stub of the limb that is severed has no further power in itself of making healing tissue. The end of the remaining stub is merely covered over by the callus, and usually remains a dead piece of wood sealed inside the trunk (Fig. 65). If wounds do not heal over speedily, germs and fungi obtain foothold in the dying wood and *rot sets in*. Hollow trees are those in which the decay-fungi have progressed into the inner wood of the trunk; *they have been infected* (Fig. 66).



FIG. 65. — KNOT IN A HEMLOCK LOG.

Large wounds should be protected with a covering of paint, melted wax, or other adhesive and lasting material,



FIG. 66.—A KNOT HOLE, and the beginning of a hollow trunk.

to keep out the germs and fungi. A covering of sheet iron or tin may keep out the rain, but it will not exclude the germs of decay; in fact, it may provide the very moist conditions that such germs need for their growth. Deep holes in trees should be treated by having all the decayed parts removed down to the clean wood, the surfaces painted or otherwise sterilized, and the hole filled with wax or cement.

Stems and roots are living, and they should not be wounded or mutilated unnecessarily. Horses should never be tied up to trees. Supervision should be exercised over persons who run telephone, telegraph, and electric light wires, to see that they do not mutilate trees. Electric light wires and trolley wires, when carelessly strung or improperly insulated, may kill trees (Fig. 67).

SUGGESTIONS. — *Forms of stems.*

1. Are the trunks of trees ever perfectly cylindrical? If not, what may cause the irregularities? Do trunks often grow more on one side than the other?

2. Slit a rapidly growing limb, in spring, with a knife blade, and watch the result during the season.

3. Examine the woodpile, and observe the variations in thickness of the annual rings, and especially of the same



FIG. 67.—ELM TREE KILLED BY A DIRECT CURRENT FROM AN ELECTRIC RAILROAD SYSTEM.

ring at different places in the circumference. Cross-sections of horizontal branches are interesting in this connection.

4. Note the enlargement at the base of a branch, and determine whether this enlargement or bulge is larger on long, horizontal limbs than on upright ones. Why does this bulge develop? Does it serve as a brace to the limb, and is it developed as the result of constant strain?

5. *Strength of stems.* The pupil should observe the fact that a stem has wonderful strength. Compare the proportionate height, diameter, and weight of a grass stem with those of the slenderest tower or steeple. Which has the greater strength? Which the greater height? Which will withstand the most wind? Note that the grass stem will regain its position even if its top is bent to the ground. Note how plants are weighted down after a heavy rain and how they recover themselves.

6. Split a cornstalk and observe how the joints are tied together and braced with fibres. Are there similar fibres in stems of pigweed, sunflower, and hollyhock?

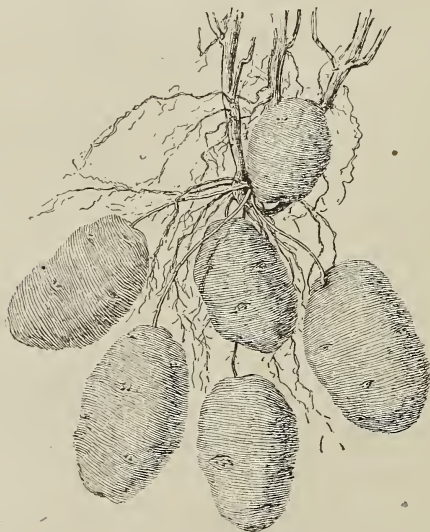


FIG. 68.—POTATO. What are roots, and what stems? Has the plant more than one kind of stem? more than two kinds? Explain.

CHAPTER X

THE STEM—ITS GENERAL STRUCTURE

THERE are two main types of stem structure in flowering plants, the differences being based on the arrangement of bundles or strands of tissue. These types are *endogenous* and *exogenous* (page 20). It will require patient laboratory work to understand what these types and structures are.

Endogenous, or Monocotyledonous Stems.—Examples of endogenous stems are all the grasses, sedges, rushes, flags, Indian corn, smilax or car-rion flower, lilies, palms and many greenhouse plants and all the cereal grains. For our study, a cornstalk may be used as a type.

A piece of *cornstalk*, either green or dead, should be in the hand of each pupil while studying this lesson. Fig. 69 will also

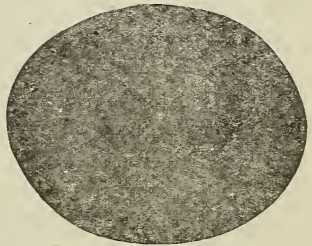


FIG. 69.—CROSS-SECTION OF CORNSTALK, showing the scattered fibro-vascular bundles. Slightly enlarged.

be of use. Is there a swelling at the nodes? Which part of the internode comes nearest to being perfectly round? There is a grooved channel running along one side of the internode: how is it placed with reference to the leaf? with reference to the groove in the internode below it? What do you find in each groove at its lower end? (In a dried stalk only traces of this are usually seen.) Does any bud on a cornstalk besides the one at

the top ever develop? Where do suckers come from? Where does the ear grow?

Cut a cross-section of the stalk between the nodes (Fig. 69). Does it have a distinct bark? The interior consists of soft "pith" and tough woody parts. The wood is found in *strands* or *fibres*. Which is more abundant? Do the fibres have any definite arrangement? Which strands are largest? Smallest? The firm smooth *rind* (which cannot properly be called a bark) consists of small, wood strands packed closely together. Grass stems are hollow cylinders; and the cornstalk, because of the lightness of its contents, is also practically a cylinder. Stems of this kind are admirably adapted for providing a strong support to leaves and fruit. This is in accordance with the well-known law that a hollow cylinder is much stronger than a solid



FIG. 70. — DIAGRAM TO SHOW THE COURSE OF FIBRO-VASCULAR BUNDLES IN MONOCOTYLEDONS.

cylinder of the same weight of material. Cut a thin slice of the inner soft part and hold it up to the light. Can you make out a number of tiny compartments or cells? These cells consist of a tissue called *parenchyma*, the tissue from which when young all the other tissues arise and differentiate (Parenchyma = *parent* + *chyma*, or tissue). The numerous walls of these cells may serve to brace the outer wall of the cylinder; but their chief function in the young stalk is to give origin to other cells. When alive they are filled with cell sap and protoplasm.

Trace the *woody strands* through the nodes. Do they ascend vertically? Do they curve towards the rind at certain places? Compare their course with the strands shown in Fig. 70. *The woody strands consist chiefly of tough fibrous cells that give rigidity*

and strength to the plant, and of long tubular interrupted canals that serve to convey sap upwards from the root and to convey food downwards from the leaves to the stem and roots.

Monocotyledons, as shown by fossils, existed before dicotyledons appeared, and it is thought that the latter were developed from ancestors of the former. It will be interesting to trace the relationship in stem structure. It will first be necessary to learn something of the structure of the wood strand.

Wood Strand in Monocotyledons and Dicotyledons.— Each wood strand (or fibro-vascular bundle) consists of two parts—the bast and the wood proper. The wood is on the side of the strand towards the centre of the stem and con-

tains large tubular canals that take the watery sap upwards from the roots. The bast is on the side towards the bark

and contains fine tubes through which diffuses the dense sap containing digested food from the leaves. In the root (Fig. 71) the bast and the wood are separate, so that there are *two kinds of strands*.

In monocotyledons, as already said, the strands (or bundles) *are usually scattered in the*

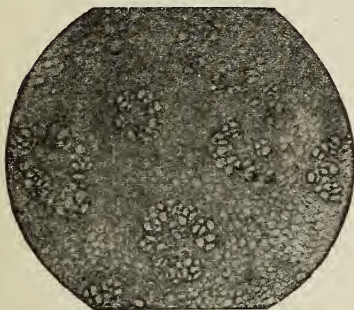


FIG. 72.— PART OF CROSS-SECTION OF ROOT-STOCK OF ASPARAGUS, showing a few fibro-vascular bundles. An endogenous stem.



FIG. 71.— DIAGRAM OF WOOD STRANDS OR FIBRO-VASCULAR BUNDLES IN A ROOT, showing the wood (x) and bast (p) separated.

stem with no definite arrangement (Figs. 72, 73). In dicotyledons the strands, or bundles, *are arranged in a*



FIG. 73. — THE SCATTERED BUNDLES OR STRANDS, in monocotyledons at *a*, and the bundles in a circle in dicotyledons at *b*.

plication continues, in tough plants, until the bundles touch (Fig. 74, right). The inner parts thus form a ring of wood and the outer parts form the inner bark or bast. New rings of wood and of bast are formed on stems of dicotyledons each year, and the age of a cut stem is easily determined.

When cross-sections of monocotyledonous and dicotyledonous bundles are examined under the microscope, it is readily seen

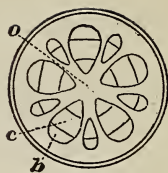
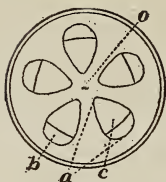


FIG. 74. — DICOTYLEDONOUS STEM OF ONE YEAR AT LEFT WITH FIVE BUNDLES, and a two-year stem at right.

o, the pith; *c*, the wood part; *b*, the bast part; *a*, one year's growth.

ring. As the dicotyledonous seed germinates, five bundles are usually formed in its hypocotyl (Fig. 74); soon five more are interposed between them, and the multi-

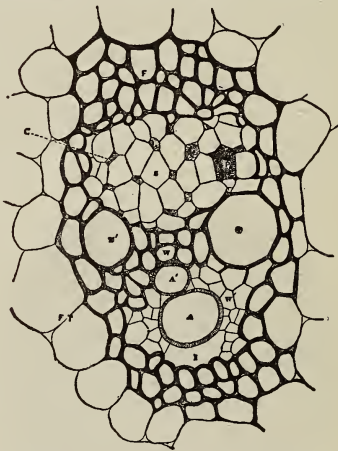


FIG. 75. — FIBRO-VASCULAR BUNDLE OF INDIAN CORN, much magnified.

A, annular vessel; *A'*, annular or spiral vessel; *TT'*, thick-walled vessels; *W*, tracheids or woody tissue; *F*, sheath of fibrous tissue surrounding the bundle; *FT*, fundamental tissue or pith; *S*, sieve tissue; *P*, sieve plate; *C*, companion cell; *I*, intercellular space, formed by tearing down of adjacent cells; *W'*, wood parenchyma.

why dicotyledonous bundles form rings of wood and monocotyledonous cannot (Figs. 75 and 76). The dicotyledonous bundle (Fig. 76) has, running across it, a layer of brick-shaped cells called **cambium**, which cells are a specialized form of the parenchyma cells and retain the power of

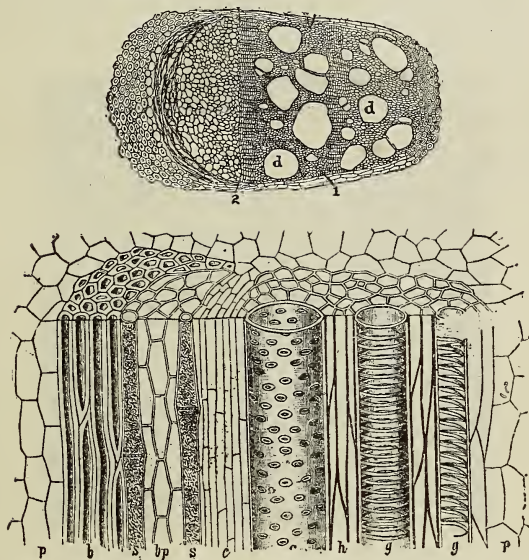


FIG. 76.—THE DICOTYLEDONOUS BUNDLE OR WOOD STRAND. Upper figure is of moonseed :

c, cambium; *d*, ducts; *1*, end of first year's growth; *2*, end of second year's growth; bast part at left and wood part at right. Lower figure (from Wettstein) is sunflower: *h*, wood-cells; *g*, vessels; *c*, cambium; *p*, fundamental tissue or parenchyma; *b*, bast; *bp*, bast parenchyma; *s*, sieve-tubes.

growing and multiplying. The bundles containing cambium are called *open bundles*. There is no cambium in monocotyledonous bundles (Fig. 75) and the bundles are called *closed bundles*. Monocotyledonous stems *soon cease to grow in diameter*. The stem of a palm tree is almost

as large at the top as at the base. As dicotyledonous plants grow, the *stems become thicker each year*, for the delicate active cambium layer forms new cells from early spring until midsummer or autumn, adding to the wood within and to the bark without. As the growth in spring is very rapid, the first wood-cells formed are much larger than the last wood-cells formed by the slow growth of the



FIG. 77.—WHITE PINE STEM, 5 years old. The outermost layer is bark.

late season, and the spring wood is less dense and lighter colored than the summer wood; hence the time between two years' growth is readily made out (Figs. 77 and 78). Because of the rapid growth of the cambium in spring and its consequent soft walls and fluid contents, the bark of trees "peels" readily at that season.

Medullary Rays.—The first year's growth in dicotyledons forms a woody ring which almost incloses the pith, and this is left as a small cylinder which does not grow

larger, even if the tree should live a century. It is not quite inclosed, however, for the narrow layers of soft cells separating the bundles remain between them (Fig. 78), forming radiating lines called **medullary rays** or **pith rays**.

The Several Plant Cells and their Functions.—In the **wood** there are some parenchyma cells that are still with thin walls, but have lost

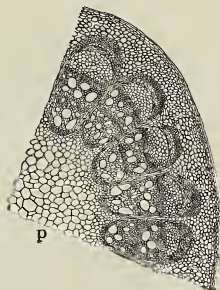


FIG. 78.—ARRANGEMENT OF TISSUES IN TWO-YEAR-OLD STEM OF MOONSEED.

p, pith; *f*, parenchyma. The fibro-vascular bundles, or wood strands, are very prominent, with thin medullary rays between.

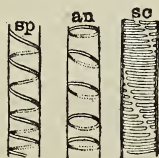


FIG. 79.—MARKINGS IN CELL WALLS OF WOOD FIBERS.

sp, spiral; *an*, annular; *sc*, scalariform.

the power of division. They are now *storage cells*. There are also wood fibres which are thick-walled and rigid (*h*, Fig.

76), and serve to *support* the sap-canals or *wood vessels* (or tracheids) that are formed by the absorption of the end

walls of upright rows of cells; the canals pass from the roots to the twigs and even to ribs of the leaves and serve to transport the root water. They are recognized (Fig. 79) by the peculiar thickening of the wall on the inner surface of the tubes, occurring in the form of spirals. Sometimes the whole wall is thickened except in spots called *pits* (*g*, Fig. 76). These thin spots (Fig. 80) allow the sap to pass to other cells or to neighboring vessels.

The cambium, as we have seen, consists of cells whose function is *growth*. These

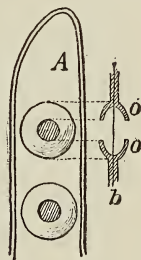


FIG. 80.—PITS IN THE CELL WALL.

Longitudinal section of wall at *b*, showing pit borders at *a*, *o*.

cells are thin-walled and filled with protoplasm. During the growing season they are continually adding to the wood within and the bark without; hence the layer moves outwards as it deposits the new woody layer within.

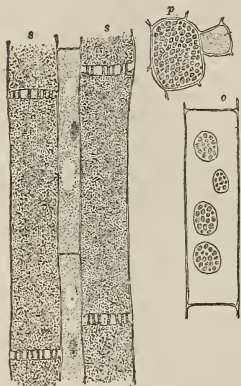


FIG. 81. — SIEVE-TUBES, *s, s*;

p shows a top view of a sieve-plate, with a companion cell, *c*, at the side; *o* shows sieve-plates in the side of the cell. In *s, s* the protoplasm is shrunken from the walls by reagents.

The bark consists of inner or *fibrous bark* or new bast (these fibres in flax become linen), the *green or middle bark* which functions somewhat as the leaves, and the *corky or outer bark*. The common word "bark" is seen therefore not to represent a homogeneous or simple structure, but rather a collection of several kinds of tissue, all separating from the wood beneath by means of cambium. The new bast contains (1) the *sieve-tubes* (Fig. 81) which transport the

sap containing organic substances, as sugar and proteids, from the leaves to the parts needing it (*s*, Fig. 76). These tubes have been formed like the wood vessels, but they have sieve-plates to allow the dense organic-laden sap to pass with sufficient readiness for purposes of rapid distribution. (2) There are also thick-walled *bast fibres* (Fig. 82) in the bast that serve for *support*. (3) There is also some parenchyma (parent tissue) in the new bast; it is now in part a *storage* tissue. Some-



FIG. 82.—THICK-WALLED BAST CELLS.

times the walls of parenchyma cells in the cortex thicken at the corners and form *brace cells* (Fig. 83) (collenchyma) for support; sometimes the whole wall is thickened, forming *grit cells* or *stone cells* (Fig.

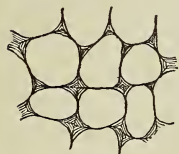


FIG. 83. — COLLENCHYMA IN WILD JEWELWEED OR TOUCH-ME-NOT (IMPATIENS).

84; examples in tough parts of pear, or in stone of fruits). Some parts serve for secretions (milk, rosin, etc.) and are called *latex tubes*.

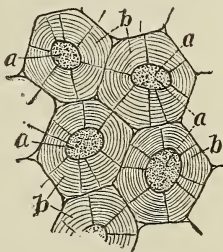


FIG. 84. — GRIT CELLS.

The outer bark of old shoots consists of *corky* cells that protect from mechanical injury, and that contain a fatty substance (suberin) impermeable to water and of service to keep in moisture. There is sometimes a cork cambium (or phellogen) in the bark that serves to extend the bark and keep it from splitting, thus increasing its power to protect.

Transport of the "Sap."—We shall soon learn that the common word "sap" does not represent a single or simple substance. We may roughly distinguish two kinds of more or less fluid contents: (1) *the root water*, sometimes called mineral sap, that is taken in by the root, containing its freight of such inorganic substances as potassium, calcium, iron, and the rest; this root water rises, we have found, in the wood vessels, — that is, in the young or "sapwood" (p. 96); (2) the *elaborated* or *organized materials* passing back and forth, especially from the leaves, to build up tissues in all parts of the plant, some of it going down to the roots and root-hairs; this organic material is transported, as we have learned, in the *sieve-tubes of the inner bast*, — that is, in the "inner bark." Removing the bark from a trunk in

a girdle will not stop the upward rise of the root water so long as the wood remains alive ; but it will stop the passage of the elaborated or food-stored materials to parts below and thus starve those parts ; and if the girdle does not heal over by the deposit of new bark, the tree will in time *starve to death*. It will now be seen that the common practice of placing wires or hoops about trees to hold them in position or to prevent branches from falling is irrational, because such wires interpose barriers over which

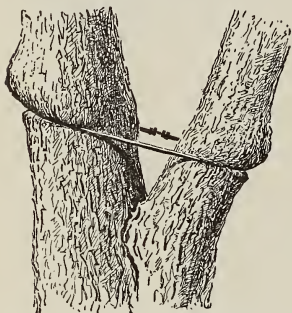


FIG. 85.—THE WRONG WAY TO BRACE A TREE. (See Fig. 118).

the fluids cannot pass ; in time, as the trunk increases in diameter, the wire girdles the tree. It is much better to bolt the parts together by rods extending through the branches (Fig. 85). These bolts should fit very tight in their holes. Why?

Wood.—The main stem or trunk, and sometimes the larger branches, are the sources of lumber and tim-

ber. Different kinds of wood have value for their special qualities. The business of raising wood, for all purposes, is known as *forestry*. The forest is to be considered as a crop, and the crop must be harvested, as much as oats or rice is harvested. Man is often able to grow a more productive forest than nature does.

Resistance to decay gives value to wood used for shingles (*cedar* and *white pine*) and for fence posts (*willow*, *cedar*, *oak*, *tamarack*, and *lodgepole pine*).

Hardness and strength are qualities of great value in building. *Live oak* is used in ships. *Red oak*, *rock maple*,

Douglas fir and *birch* are used for floors. The best flooring is sawn with the straight edges of the annual rings upwards; tangential sawn flooring may splinter. *Ebony* is a tropical wood used for flutes, black piano keys, and fancy articles. *Ash* is straight and elastic; it is used for handles for light implements. *Hickory* is very strong as well as elastic, and is superior to ash for handles, spokes, and other uses where strength is wanted. Hickory is never sawn into lumber, but is split or turned. The "second growth," which sprouts from stumps, is most useful, as it splits readily. Fast-growing hickory in rich land is most valuable. The supply of useful hickory is being rapidly exhausted. All these hardwoods are native of eastern Canada and the eastern part of the United States. Red oak, hard maple, and birch are largely imported for house finishings.

Softness is often important. *White pine* because of its lightness and the ease with which it can be worked was formerly used for cheaper grades of house finishing and all general work. It is now becoming exceedingly scarce and its place is being taken by the various pines, cedar, and spruce of British Columbia, and the native white spruce. *Douglas fir* is used where strength is required, as in joists and scantling. An inferior lumber for rough purposes is frequently made of the native American aspen, while white cedar is largely imported for posts. *Cedar* is readily carved and has a unique use in the making of chests for clothes, as its odor repels moths and other insects. *Willow* is useful for baskets and light furniture. *Basswood* or *linden* is used for boats.

Beauty of grain and polish gives wood value for furniture, pianos, and the like. *Mahogany* and *white oak* are most beautiful, although red oak is also used. Oak logs

which are first quartered and then sawn radially expose the beautiful silver grain (medullary rays). Fig. 86 shows one

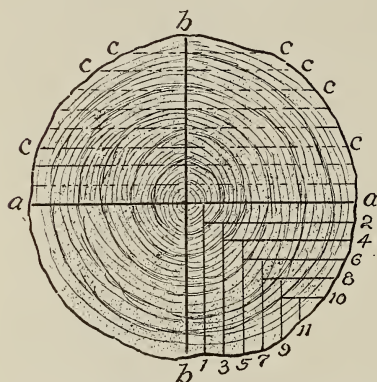


FIG. 86. — THE MAKING OF ORDINARY BOARDS, AND ONE WAY OF MAKING "QUARTERED" BOARDS.

mode of quartering. The log is quartered on the lines *a, a, b, b*; then succeeding boards are cut from each quarter at 1, 2, 3, etc. The nearer the heart the better the "grain": why? Ordinary boards are sawn tangentially, as *c, c*. *Curly pine*, *curly walnut*, and *bird's-eye maple* are woods that owe their

beauty of grain to wavy lines or buried knots. Merely a stump of curly walnut is worth several hundred dollars. Such wood is sliced very thin for veneering and glued over other woods in making pianos and other pieces. If the cause of wavy grain could be found out and such wood grown at will, the discovery would be very useful. *Maple* and *ash* are much used for furniture. *Birch* may be colored so as very closely to represent mahogany, and it is extensively used.

Special Products of Trees. — Cork from the bark of the cork oak in Spain, latex from the rubber and sap from the sugar-maple trees, turpentine from pine, tannin from oak bark, Peruvian bark from cinchona, are all useful products.

SUGGESTIONS. —

1. *Parts of a root and stem through which liquids rise.*
- a. Pull up a small plant with abundant leaves, cut off the root so

as to leave two inches or more on the plant (or cut a leafy shoot of squash or other strong-growing coarse plant), and stand it in a bottle with a little water in the bottom which has been colored with red ink (eosin). After three hours examine the root; make cross-sections at several places. Has the water colored the axis cylinder? The cortex? What is your conclusion? Stand some cut flowers or a leafy plant with cut stem in the same solution and examine as before: conclusion? b. Girdle a twig of a rapidly growing bush (as willow) in early spring when growth begins (*a*) by very carefully removing only the bark, and (*b*) by cutting away also the sapwood. Under which condition do the leaves wilt? Why? c. Stand twigs of willow in water; after roots have formed under the water, girdle the twig (in the two ways) above the roots. What happens to the roots, and why? d. Observe the swellings on trees that have been girdled or very badly injured by wires or otherwise: where are these swellings, and why?

2. *Kinds of wood.* Let each pupil determine the kind of wood in the desk, the floor, the door and window casings, the doors themselves, the sash, the shingles, the fence, and in the small implements and furniture in the room; also what is the cheapest and the most expensive lumber in the community. How many kinds of wood does the pupil know, and what are their chief uses?

NOTE TO TEACHER.—The work in this chapter is intended to be mainly descriptive, for the purpose of giving the pupil a rational conception of the main vital processes associated with the stem, in such a way that he may translate it into his daily thought. It is not intended to give advice for the use of the compound microscope. If the pupil is led to make a careful study of the text, drawings, and photographs on the preceding and the following pages, he will obtain some of the benefit of studying microscopic sections without being forced to spend time in mastering microscopic technique. If the school is equipped with compound microscopes, a teacher is probably chosen who has the necessary skill to manipulate them and the knowledge of anatomy and physiology that goes naturally with such work; and it would be useless to give instruction in such work in a text of this kind. The writer is of the opinion that the introduction of the compound microscope into first courses in botany has been productive of harm. Good and vital teaching demands first that the pupil have a normal, direct, and natural relation to his subject, as he commonly meets it, that the obvious and significant features of the plant world be explained to him and be made a means of training him. The beginning pupil cannot be expected to know the fundamental physiological processes, nor is it necessary that these processes

should be known in order to have a point of view and trained intelligence on the things that one customarily sees. Many a pupil has had a so-called laboratory course in botany without having arrived at any real conception of what plants mean, or without having had his mind opened to any real sympathetic touch with his environment. Even if one's knowledge be not deep or extensive, it may still be accurate as far as it goes, and his outlook on the subject may be rational.

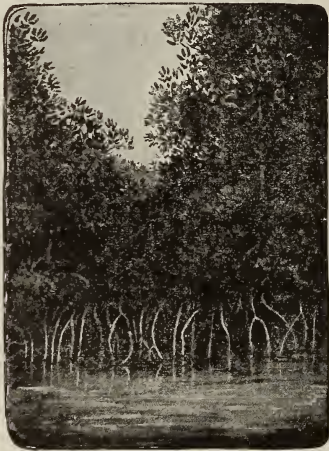


FIG. 87.—THE MANY-STEMMED THICKETS OF MANGROVE OF SOUTHERNMOST SEACOASTS, many of the trunks being formed of aërial roots.

CHAPTER XI

LEAVES — FORM AND POSITION

LEAVES may be studied from four points of view, — with reference (1) to their *kinds* and *shapes*; (2) their *position*, or *arrangement* on the plant; (3) their *anatomy*, or *structure*;

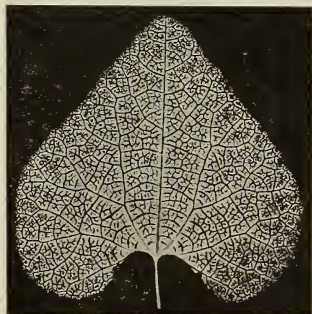


FIG. 88. — A SIMPLE NETTED-VEINED LEAF.

(4) their *function*, or the work they perform. This chapter is concerned with the first two categories.



FIG. 90. — COMPOUND OR BRANCHED LEAF OF BRAKE (a common fern).



FIG. 89. — A SIMPLE PARALLEL-VEINED LEAF.

Kinds. — Leaves are **simple** or **unbranched** (Figs. 88, 89), and **compound** or **branched** (Fig. 90).

The method of compounding or branching follows the mode of veining. The veining, or **venation**, is of two general kinds: in some plants the main veins diverge, and there is a conspicuous network of smaller veins; such leaves are **netted-veined**. They are characteristic of the dicotyledons. In other plants the main veins are parallel, or nearly so, and there is no conspicuous network; these are **parallel-veined** leaves (Figs. 89, 102). These leaves are the rule in monocotyledonous plants. The venation of netted-veined leaves is **pinnate** or feather-like when the veins arise from the side of a continuous midrib (Fig. 91); **palmate** or **digitate** (hand-like) when the veins arise from the apex of the petiole (Figs. 88, 92). If leaves were divided between the main veins, the former would be pinnately and the latter digitately compound.



FIG. 91. — COMPLETE LEAVES OF WILLOW.

It is customary to speak of a leaf as compound only when the parts or branches are completely separate blades,

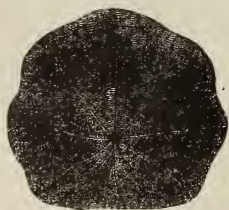


FIG. 92. — DIGITATE-VEINED PELTATE LEAF OF GARDEN NASTURTIUM.

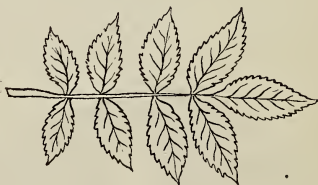


FIG. 93. — PINNATELY COMPOUND LEAF OF GREEN ASH.

as when the division extends to the midrib (Figs. 90, 93, 94, 95). The parts or branches are known as **leaflets**.

Sometimes the leaflets themselves are compound, and the whole leaf is then said to be **bi-compound** or **twice-com-**



FIG. 94.—DIGITATELY COMPOUND LEAF
OF VIRGINIA CREEPER.



FIG. 95.—LEAF OF POISON IVY.

pound (Fig. 90). Some leaves are three-compound, four-compound, or five-compound. The terms pinnately-compound and digitately-compound are also used (Figs. 93 and 94). **Decompound** is a general term to express any degree of compounding beyond twice-compound.

Leaves that are not divided as far as to the midrib are said to be:

lobed, if the openings or sinuses do not extend deeper than about half way between the margin and the centre of the blade (Fig. 96);

cleft, if the sinuses extend half way down or more, and especially when they are sharp;



FIG. 96.—LOBED LEAF OF
WILD HOP.



FIG. 97.—DIGITATELY PARTED LEAVES
OF BEGONIA.

parted, if the sinuses reach two thirds or more to the midrib (Fig. 97); **divided**, if sinuses reach nearly or quite to the midrib.

The parts are called lobes, divisions, or segments, rather than leaflets. The leaf may be pinnately or digitately

lobed, parted, cleft, or divided. A pinnately parted or cleft leaf is sometimes said to be **pinnatifid**.

Leaves may have one or all of three parts — blade, or expanded part; petiole, or stalk; stipules, or appendages

at the base of the petiole. A leaf that has all three of these parts is said to be **complete** (Figs. 91, 106). The stipules are often green and leaflike and perform the function of foliage, as in



FIG. 98.—OBLONG-OVATE SESSILE LEAVES.

the pea and Japanese quince (the latter common in yards).

Leaves and leaflets that have no stalks are said to be **sessile** (Figs. 98, 103), *i.e.* sitting. Find several examples.

The same is said of flowers and fruits. The blade of a sessile leaf may partly or wholly surround the stem, when it is said to be **clasp- ing**. Examples: aster (Fig. 99), corn. In some cases the leaf runs down the stem, forming a wing; such leaves are said to be **decurent** (Fig. 100). When opposite sessile leaves are joined by their bases, they are said to be **connate** (Fig. 101).



FIG. 99.—CLASP-
ING LEAF OF A
WILD ASTER.

Leaflets may have one or all of these

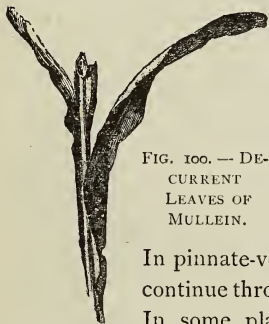


FIG. 100.—DE-
CURRENT
LEAVES OF
MULLEIN.

three parts, but the stalks of leaflets are called **petiolules** and the stipules of leaflets are called **stipels**. The leaf of the garden bean has leaflets, petiolules, and stipels.

The blade is usually attached to the petiole by *its lower edge*.

In pinnate-veined leaves, the petiole seems to continue through the leaf as a **midrib** (Fig. 91).

In some plants, however, the petiole joins the blade inside or beyond the margin (Fig. 92). Such leaves are said to be **peltate** or shield-shaped. This mode of attachment is particularly common in floating leaves. Peltate leaves are usually digitate-veined.

How to Tell a Leaf.—It is often difficult to distinguish compound leaves from leafy branches, and leaflets



FIG. 101.—TWO PAIRS OF CONNATE
LEAVES OF HONEYSUCKLE.

from leaves. As a rule leaves can be distinguished by the following tests: (1) Leaves are *temporary structures*, sooner or later falling. (2) Usually *buds are borne in their axils*. (3) Leaves are usually *borne at joints or nodes*. (4) They arise on wood of the *current year's growth*. (5) They have a more or less *definite arrangement*. When leaves fall, the twig that bore them remains; when leaflets fall, the main petiole or stalk that bore them also falls.

♣ **Shapes.** — Leaves and leaflets are infinitely variable in shape. Names have been given to some of the more definite or regular shapes. These names are a part of the language of botany. The names represent ideal or typical shapes; there are no two leaves alike and very few that perfectly conform to the definitions. The shapes are likened to those of familiar objects or of geometrical figures. Some of the commoner shapes are as follows (name original examples in each class):



FIG. 102. —
LINEAR-
ACUMINATE
LEAF OF
GRASS.

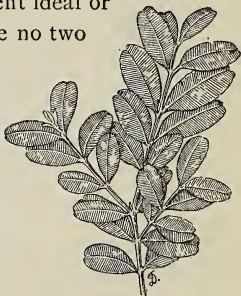


FIG. 103. — SHORT-OB-
LONG
LEAVES OF BOX.

Linear, several times longer than broad, with the sides nearly or quite parallel. Spruces and most grasses are examples (Fig. 102). In linear leaves, the main veins are usually parallel to the midrib.

Oblong, twice or thrice as long as broad, with the sides parallel for most of their length. Fig. 103 shows the short-oblong leaves of the box, a plant that is used for permanent edgings in gardens.

Elliptic differs from the oblong in having the sides gradually tapering to either end from the middle. The saskatoon and many of our trees and shrubs have leaves of this shape. Fig. 104.

Lanceolate, four to six times longer than broad, widest below the middle, and tapering to either end. Some of the narrow-leaved willows are examples. Most of the willows and the cherries have oblong-lanceolate leaves.

Spatulate, a narrow leaf that is broadest towards the apex. The top is usually rounded.

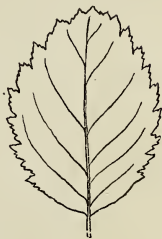


FIG. 104.—
ELLIPTIC LEAF.



FIG. 105.—OBLONG-LANCEOLATE
LEAF OF NANNY BERRY.



FIG. 106.—COMPOUND LEAF OF WILD
ROSE, showing leaflets and stipules.

Ovate, shaped somewhat like the longitudinal section of an egg: about twice as long as broad, tapering from near the base to the apex. This is one of the commonest leaf forms.

Obovate, ovate inverted, — the wide part towards the apex.



This is not a common form of leaf but is not uncommon in leaflets of digitate leaves. This form is commonest in leaflets of digitate leaves: why?

Reniform, kidney-shaped. This form is sometimes seen in wild plants, particularly in root-leaves. Leaves of marsh marigold are nearly reniform.



Orbicular, circular in general outline. Very few leaves are perfectly circular, but there are many that are nearer circular than any other shape (Fig. 107).

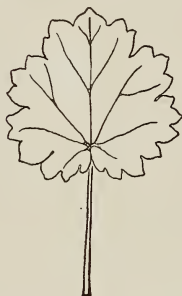


FIG. 107.—ORBICULAR LOBED
LEAF OF ALUM ROOT.



FIG. 108.—TRUNCATE
LEAF OF TULIP TREE.

The shape of many leaves is described in combinations of these terms: as **ovate-lanceolate**, **lanceolate-oblong**.

The shape of the base and apex of the leaf or leaflet is often characteristic. The base may be **rounded** (Fig. 104), **tapering** (Fig. 93), **cordate** or heart-shaped as aspen, **truncate** or squared as if cut off. The apex may be blunt or **obtuse**, **acute** or sharp, **acuminate** or long-pointed, **truncate** (Fig. 108). Name examples.

The shape of the margin is also characteristic of each kind of leaf. The margin is **entire** when it is not indented or cut in any way (Figs. 99, 103). When not

entire, it may be **undulate** or wavy (Fig. 92), **serrate** or saw-toothed (Fig. 105), **dentate** or more coarsely notched (Fig. 95), **crenate** or round-toothed, **lobed**, and the like. Give examples.

Leaves often differ greatly in form on the same plant. Observe the different shapes of leaves on the young and older growths of most plants as wild grapes and vigorous squash and pumpkin vines. In some cases there may be simple and compound leaves on the same plant. The root leaves are frequently simple while those on the stem are compound. This is common on the wild parsnip of the prairie, and on some of the buttercups. Different degrees of compound-ing, even in the same leaf, may often be found on the Manitoba maple.



FIG. 109.—DIFFERENT FORMS OF LEAVES FROM ONE PLANT OF GREEN ASH.

Remarkable differences in forms are seen by comparing seed-leaves with mature leaves of many plants (Fig. 30).

The Leaf and its Environment.—The form and shape of the leaf often have direct relation to the *place in which the leaf grows*. *Floating leaves are usually expanded and flat*, and the petiole varies in length with the depth of the water. *Submerged leaves are usually linear or thread-like*, or are cut into very narrow divisions: thereby more surface is exposed, and possibly the leaves are less injured by moving water. Compare the sizes of the leaves on the ends of branches with those at the base of the

branches or in the interior of the tree top. In dense foliage masses, the petioles of the lowermost or undermost leaves *tend to elongate*—to push the leaf to the light.

On the approach of winter the leaf usually ceases to work, and dies. It may drop, when it is said to be **deciduous**; or it may remain on the plant, when it is said to be **persistent**. If persistent leaves remain green during the winter, the plant is said to be **evergreen**. Give examples in each class. Most leaves fall by breaking off at the lower end of the petiole with a *distinct joint or articulation*. There are many leaves, however, that wither and hang on the plant until torn off by the wind; of such are the leaves of grasses, sedges, lilies, orchids, and other plants of the monocotyledons. Most leaves of this character are parallel-veined.

Leaves also die and fall from lack of light. Observe the yellow and weak leaves in a dense tree top or in any thicket. Why do the lower leaves die on house plants? Note the carpet of needles under the pines. All evergreens shed their leaves after a time. Counting back from the tip of a pine or spruce shoot, determine how many years the leaves persist. In some spruces a few leaves may be found on branches ten or more years old.

Arrangement of Leaves.—Most leaves have a regular *position or arrangement* on the stem. *This position or direction is determined largely by exposure to sunlight.* In temperate climates they usually hang in such a way that they receive the greatest amount of light. One leaf shades the other to the least possible degree. If the plant were placed in a new position with reference to light, the leaves would make an effort to turn their blades.

When leaves are opposite the pairs usually alternate. That is, if one pair stands north and south, the next pair

stands east and west. Note the Manitoba maple shoot, on the left in Fig. 110. *One pair does not shade the pair beneath.* The leaves are in four vertical ranks.

There are several kinds of alternate arrangement. In the elm shoot, in Fig. 110, the third bud is vertically above the first. This is true no

matter which bud is taken as the starting point. Draw a thread around the stem until the two buds are joined. Set a pin at each bud. Observe that two buds are passed (not counting the last) and that the thread makes one circuit of the stem. Representing the number of buds by a denominator, and the number of circuits by a numerator, we have the fraction $\frac{1}{2}$, which expresses

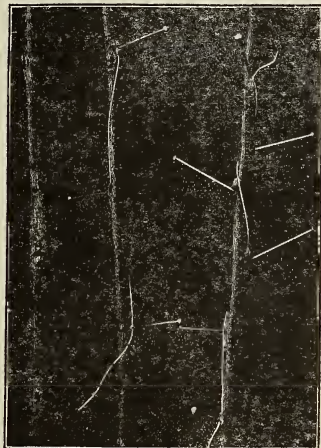


FIG. 110.—PHYLLOTAXY OF MANITOBA MAPLE, ELM, CHERRY.

the part of the circle that lies between any two buds. That is, the buds are one half of 360 degrees apart, or 180 degrees. Looking endwise at the stem, the leaves are seen to be 2-ranked. Note that in the cherry shoot (Fig. 110, right) the thread makes two circuits and five buds are passed: *two-fifths represents the divergence between the buds.* The leaves are 5-ranked.

Every plant has its own arrangement of leaves. For opposite leaves, see maple, box-elder, ash, lilac, honeysuckle, mint. For 2-ranked arrangement, see all grasses, Indian corn, basswood, elm. For 3-ranked arrangement,

see all sedges. For 5-ranked (which is one of the commonest), see cherry, plum, saskatoon, poplar, willow. For 8-ranked (which is not common), see some willows. More complicated arrangements occur in bulbs, house leeks, and other condensed parts. The buds or "eyes" on a potato tuber, which is an underground stem (why?), show a spiral arrangement (Fig. III). *The arrangement of leaves on the stem is known as phyllotaxy* (literally, "leaf arrangement"). Make out the phyllotaxy on six different plants nearest the schoolhouse door.



FIG. III. —
PHYLLOTAXY
OF THE PO-
TATO TUBER.
Work it out
on a fresh
long tuber.

The arrangement of leaves on the stem is known as phyllotaxy (literally, "leaf arrangement"). Make out the phyllotaxy on six different plants nearest the schoolhouse door.

In some plants, several leaves occur at one level, being arranged in a circle around the stem. Such leaves are said to be **verticillate**, or **whorled**. Leaves arranged in this way are usually narrow: why?

Although a definite arrangement of leaves is the rule of most plants, *it is subject to modification*. On shoots that receive the light only from one side or that grow in difficult positions, the arrangement may not be definite. Examine shoots that grow on the under side of dense tree tops or in other partially lighted positions.

SUGGESTIONS. —

1. The pupil should match leaves to determine whether any two are alike. Why? Compare leaves from the same plant in size, shape, color, form of margin, length of petiole, venation, texture (as to thickness or thinness), stage of maturity, smoothness or hairiness. Let the pupil take an average leaf from each of the first ten different kinds of plants that he meets and compare them as to the above points, and also name the shapes. Determine how the various leaves resemble and differ.

2. Describe the stipules of rose, willow, violet, pea, or others.

3. In what part of the world are parallel-veined leaves the more common? Do you know of parallel-veined leaves that have lobed or dentate margins?

4. What becomes of dead leaves? Why is there no grass or other undergrowth under pine and spruce trees?

5. Name several leaves that are useful for decorations. Why are they useful? What trees in your vicinity are most esteemed as shade trees? What is the character of their foliage?

6. How do leaves curl when they wither? Do different leaves behave differently in this respect?

7. What kinds of leaves do you know to be eaten by insects? By cattle? By horses? What kinds are used for human food?

8. How would you describe the shape of leaf of elm? Manitoba maple? wild hop? rose? red osier dogwood? saskatoon? poplar? strawberry? ash? silverweed? spruce? Are any of the foregoing leaves compound? How do you describe the shape of a compound leaf?

9. How many sizes of leaves do you find on the bush or tree nearest the schoolroom door? How many colors or shades? How many lengths of petioles? Bring in all the shapes of leaves that you can find.



FIG. 112.—ALFALFA. Describe the leaves. For what is the plant used?

CHAPTER XII

LEAVES—STRUCTURE OR ANATOMY

BESIDES the **framework**, or system of veins found in blades of all leaves, there is a soft cellular tissue called **mesophyll**, or **leaf parenchyma**, and an **epidermis** or skin that covers the entire outside part.

Mesophyll.—The mesophyll is *not all alike or homogeneous*. The upper layer is composed of elongated cells placed perpendicular to the surface of the leaf. These are called **palisade cells**. These cells are usually filled

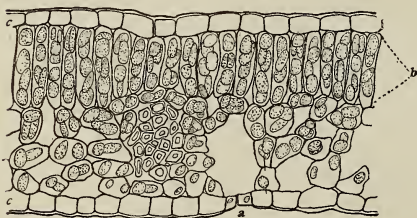


FIG. 113.—SECTION OF A LEAF, showing the air spaces. Breathing-pore or stoma at *a*. The palisade cells which chiefly contain the chlorophyll are at *b*. Epidermal cells at *c*.

with green bodies called **chlorophyll grains**. The grain contains a great number of chlorophyll drops imbedded in the protoplasm. Below the palisade cells is the

spongy **parenchyma**, composed of cells more or less spherical in shape, irregularly arranged, and provided with many intercellular air cavities (Fig. 113). In leaves of some plants exposed to strong light there may be more than one layer of palisade cells, as in the India-rubber plant and oleander. Ivy when grown in bright light will develop two such layers of cells, but in shaded places it may be

found with only one. Such plants as iris and cat-tail, which have both surfaces of the leaf equally exposed to sunlight, usually have a palisade layer beneath each epidermis.

Epidermis.—The outer or epidermal cells of leaves do not bear chlorophyll, but are usually so transparent that the green mesophyll can be seen through them. They often become very thick-walled, and are in most plants devoid of all protoplasm except a thin layer lining the walls, the cavities being filled with cell sap. This sap is sometimes colored, as in the under epidermis of begonia leaves. It is not common to find more than one layer of epidermal cells forming each surface of a leaf. The epidermis *serves to retain moisture* in the leaf and as a general *protective covering*. In desert plants the epidermis, as a rule, is very thick and has a dense cuticle, thereby preventing loss of water.

There are various *outgrowths of the epidermis*. **Hairs** are the chief of these. They may be (1) **simple**, as on primula, geranium, nægelia; (2) **once branched**, as on wall-flower; (3) **compound**, as on verbascum or mullein; (4) **disk-like**, as on shepherdia; (5) **stellate**, or star-shaped, as on rock cress. In some cases the hairs are **glandular**, as in Chinese primrose of the greenhouses (*Primula Sinensis*) and certain hairs of pumpkin flowers. The hairs often protect the breathing pores, or stomates, from dust and water.

Stomates (sometimes called **breathing-pores**) are *small openings or pores* in the epidermis of leaves and soft stems that allow the passage of air and other gases and vapors (*stomate* or *stoma*, singular; *stomates* or *stomata*, plural). They are *placed near the large intercellular spaces* of the mesophyll, usually in positions least affected by direct

sunlight. Fig. 114 shows the structure. There are two guard-cells at the mouth of each stoma, which may in most cases open or close the passage as the conditions of the atmosphere may require. The guard-cells contain

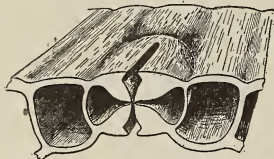


FIG. 114. — DIAGRAM OF STOMATE OF IRIS (Osterhout).

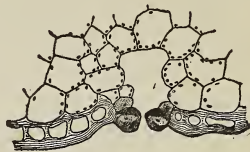


FIG. 115. — STOMATE OF IVY, showing compound guard-cells.

chlorophyll. In Fig. 115 is shown a case in which there are compound guard-cells, that of ivy. On the margins of certain leaves, as of fuchsia, impatiens, cabbage, are openings known as **water-pores**.

Stomates are very numerous, as will be seen from the numbers showing the pores to each square inch of leaf surface :

	Lower surface	Upper surface
Peony	13,790	None
Holly	63,600	None
Lilac	160,000	None
Mistletoe	200	200
Tradescantia	2,000	2,000
Garden Flag (iris)	11,572	11,572

The arrangement of stomates on the leaf *differs with each kind of plant*. Fig. 116 shows stomates and also the outlines of contiguous epidermal cells.



FIG. 116. — STOMATES OF GERANIUM LEAF.

The function or work of the stomates is to *regulate the passage of gases* into and out of the plant. The directly active organs or parts are guard-cells, on either side the opening. One method of opening is as follows: The

thicker walls of the guard-cells (Fig. 114) absorb water from adjacent cells, these thick walls buckle or bend and part from each other at their middles on either side of the opening, causing the stomate to open, when the air gases may be taken in and the leaf gases may pass out. When moisture is reduced in the leaf tissue, the guard cells part with some of their contents, the thick walls straighten, and the faces of the two opposite ones come together, thus closing the stomate and preventing any water vapor from passing out. *When a leaf is actively at work making new organic compounds, the stomates are usually open; when unfavorable conditions arise, they are usually closed.* They also commonly close at night, when growth (or the utilizing of the new materials) is most likely to be active. It is sometimes safer to fumigate greenhouses and window gardens at night, for the noxious vapors are less likely to enter the leaf. Dust may clog or cover the stomates. Rains benefit plants by washing the leaves as well as by providing moisture for the roots.

Lenticels. — On the young, woody twigs of many plants (marked in alder, cherry, birch) there are small corky spots or elevations known as **lenticels** (Fig. 117). They mark the location of some loose, cork cells that function as stomates, for *green shoots*, as well as leaves, take in and discharge gases; that is, soft, green twigs *function as leaves*. Under some of these twig stomates, corky material may form and the opening is torn and enlarged: *the lenticels are successors to the stomates*. The stomates lie in the epi-



FIG. 117. — LENTICELS ON YOUNG SHOOT OF DOGWOOD (CORNUS).

dermis, but as the twig ages the epidermis perishes and the bark becomes the external layer. *Gases continue to pass in and out through the lenticels*, until the branch becomes heavily covered with thick, corky bark. With the growth of the twig, the lenticel scars enlarge lengthwise or crosswise or assume other shapes, often becoming characteristic markings.

Fibro-vascular Bundles. — We have studied the fibro-vascular bundles of stems (Chap. X). These stem bundles *continue into the leaves, ramifying into the veins*, carrying the soil water inwards and bringing, by diffusion, the elaborated food out through the sieve-cells. Cut across a petiole and notice the hard spots or areas in it; strip these parts lengthwise of the petiole: what are they?

Fall of the Leaf. — In most, common, deciduous plants, when the season's work for the leaf is ended, the nutritious matter may be withdrawn, and *a layer of corky cells is completed over the surface of the stem where the leaf is attached. The leaf soon falls.* It often falls even before it is killed by frost. Deciduous leaves begin to show the surface line of articulation in the early growing season. This articulation may be observed at any time during the summer. The area of the twig once covered by the petioles is called the **leaf-scar** after the leaf has fallen. In Chap. XV are shown a number of leaf-scars. In the Manitoba maple or box elder, the leaf-scar is in the form of a ring almost surrounding the bud, for the bud is covered by the hollowed end of the petiole; the leaf of sumac is similar. Examine with a hand lens leaf-scars of several woody plants. Note the number of bundle-scars in each leaf-scar. Sections may be cut through a leaf-scar and examined with the microscope. Note the character of cells that cover the leaf-scar surface.

SUGGESTIONS. —

1. *To study epidermal hairs*: For this study, use the leaves of any hairy or woolly plant. A good hand lens will reveal the identity of many of the coarser hairs. A dissecting microscope will show them still better. For the study of the cell structure, a compound microscope is necessary. Cross-sections may be made so as to bring hairs on the edge of the sections; or in some cases the hairs may be peeled or scraped from the epidermis and placed in water on a slide. Make sketches of the different kinds of hairs. It is good practice for the pupil to describe leaves in respect to their covering: Are they smooth on both surfaces? Or hairy? Woolly? Thickly or thinly hairy? Hairs long or short? Standing straight out or lying close to the surface of the leaf? Simple or branched? Attached to the veins or the plane surface? Color? Most abundant on young leaves or old? Place a hairy or woolly leaf under water. Does the hairy surface appear silvery? Why?

2. *Other questions*: Why is it good practice to wash the leaves of house plants? Describe the leaf-scars on six kinds of plants: size, shape, color, position with reference to the bud, bundle-scars. Do you find leaf-scars on monocotyledonous plants — corn, cereal grains, lilies? Note the table on page 88. Can you suggest a reason why there are equal numbers of stomates on both surfaces of leaves of flags, and none on upper surface of other leaves? Suppose you pick a leaf of lilac (or some larger leaf), seal the petiole with wax and then rub the under surface with vaseline; on another leaf apply the vaseline to the upper surface; which leaf withers first, and why? Make a similar experiment with iris or blue flag. Why do leaves and shoots of house plants turn towards the light? What happens when the plants are turned around? Note position of leaves of beans, clover, oxalis, alfalfa, at night.

CHAPTER XIII

LEAVES — FUNCTION OR WORK

WE have discussed (in Chap. VIII) the work or function of roots and also (in Chap. X) the function of stems. We are now ready to complete the view of the main vital activities of plants by considering the function of the green parts (leaves and young shoots).

Sources of Food. — The ordinary green plant has but *two sources from which to secure food, — the air and the soil.* When a plant is thoroughly dried in an oven, the water passes off; *this water came from the soil.* The remaining part is called the **dry substance** or **dry matter**. If the dry matter is burned in an ordinary fire, only the **ash** remains; *this ash came from the soil.* The part that passed off as gas in the burning *contained the elements that came from the air;* it also contained some of those that came from the soil — all those (as nitrogen, hydrogen, chlorine) that are transformed into gases by the heat of a common fire. The part that comes from the soil (the ash) is small in amount, being considerably less than 10 per cent and sometimes less than 1 per cent. *Water is the most abundant, single constituent or substance of plants.* In a corn plant at the roasting-ear stage, about 80 per cent of the substance is water. A fresh turnip is over 90 per cent water. Fresh wood of the apple tree contains about 45 per cent of water.

Carbon. — *Carbon enters abundantly into the composition of all plants.* Note what happens when a plant is burned

without free access of air, or smothered, as in a charcoal pit. *A mass of charcoal remains, almost as large as the body of the plant.* Charcoal is almost pure carbon, the ash present being so small in proportion to the large amount of carbon that we look on the ash as an impurity. Nearly half of the dry substance of a tree is carbon. Carbon goes off as a gas when the plant is *burned in air*. It does not go off alone, but in combination with oxygen in the form of *carbon dioxide gas*, CO_2 .

The green plant secures its carbon from the air. In other words, much of the *solid matter* of the plant comes from *one of the gases of the air*. By volume, *carbon dioxide forms only a very small fraction of 1 per cent of the air*. It would be very disastrous to animal life, however, if this percentage were much increased, for it excludes the life-giving oxygen. Carbon dioxide is often called "foul gas." It may accumulate in old wells, and an experienced person will not descend into such wells until they have been tested with a torch. If the air in the well will not support combustion, — that is, if the torch is extinguished, — it usually means that carbon dioxide has drained into the place. The air of a closed schoolroom often contains far too much of this gas, along with little solid particles of waste matters. Carbon dioxide is often known as carbonic acid gas.

Appropriation of the Carbon. — *The carbon dioxide of the air readily diffuses itself into the leaves and other green parts of the plant.* The leaf is delicate in texture, and when very young the air can diffuse directly into the tissues. The stomates, however, are the special inlets adapted for the admission of gases into the leaves and other green parts. Through these stomates, or diffusion-pores, the outside air enters into the air-spaces of the plant, and is finally absorbed by the little cells containing the living matter.

Chlorophyll ("leaf green") is the agent that secures the energy by means of which carbon dioxide is utilized. This material is contained in the leaf cells in the form of grains (p. 86); the grains themselves are protoplasm, only the coloring matter being chlorophyll. *The chlorophyll bodies or grains are often most abundant near the upper surface of the leaf, where they can secure the greatest amount of light.* Without this green coloring matter, there would be no reason for the large, flat surfaces which the leaves possess, and no reason for the fact that the leaves are borne most abundantly at the ends of branches, where the light is most available. Plants with colored leaves, as coleus, have chlorophyll, but it is masked by other coloring matter. This other coloring matter is usually soluble in hot water: boil a coleus leaf and notice that it becomes green and the water becomes colored.

Plants grown in darkness are yellow and slender, and do not reach maturity. Compare the potato sprouts that have grown from a tuber lying in the dark cellar with those that have grown normally in the bright light. The shoots have become slender and are devoid of chlorophyll; and when the food that is stored in the tuber is exhausted, these shoots will die, having lived useless lives. A plant that has been grown in darkness from the seed will soon die, although for a time the little seedling will grow very tall and slender: why? *Light favors the production of chlorophyll*, and the chlorophyll is the agent in the making of *the organic carbon compounds*. Sometimes chlorophyll is found in buds and seeds, but in such cases they are not in perfectly dark places. Notice how potato tubers develop chlorophyll, or become green, when exposed to light.

Photosynthesis. — *Carbon dioxide diffuses into the leaf; during sunlight it is used, and oxygen is given off.* How the

carbon dioxide which is thus absorbed may be used in making an organic food is a complex question, and need not be studied here; but it may be stated that carbon dioxide and water are the constituents. Complex compounds are built up out of simpler ones.

Chlorophyll absorbs certain light rays, and the energy thus directly or indirectly obtained is used by the living matter in uniting the carbon dioxide absorbed from the air with some of the water brought up from the roots. The ultimate result usually is starch. The process is obscure, but sugar is generally one step; and our first definite knowledge of the product begins when starch is deposited in the leaves. The process of using the carbon dioxide of the air has been known as carbon assimilation, but the term now most used is **photosynthesis** (from two Greek words, meaning *light* and *to put together*).

Starch and Sugar. — *All starch is composed of carbon, hydrogen, and oxygen ($C_6H_{10}O_5$)_n.* The sugars and the substance of cell walls are very similar to it in composition. All these substances are called **carbohydrates**. In making fruit sugar from the carbon and oxygen of carbon dioxide and from the hydrogen and oxygen of the water, *there is a surplus of oxygen* ($6 \text{ parts } CO_2 + 6 \text{ parts } H_2O = C_6H_{12}O_6 + 6 O_2$). It is this oxygen that is given off into the air during sunlight.

Digestion. — *Starch is in the form of insoluble granules. When such food material is carried from one part of the plant to another for purposes of growth or storage, it is made soluble before it can be transported.* When this starchy material is transferred from place to place, it is usually changed into sugar by the action of a diastase. *This is a process of digestion.* It is much like the change of starchy foodstuffs to sugary foods by the saliva.

Distribution of the Digested Food. — After being changed to the soluble form, *this material is ready to be used in growth*, either in the leaf, in the ^{material} stem, or in the roots.

With other more complex products it is then *distributed throughout all of the growing parts of the plant*; and when passing down to the root, it seems to pass more readily through the *inner bark*, in plants which have a definite bark. This gradual downward diffusion through the inner bark of materials suitable for growth is the process referred to when the "descent of sap" is mentioned. Starch and other products are often *stored in one growing season to be used in the next season*. If a tree is constricted or strangled by a wire around its trunk (Fig. 118), the digested food

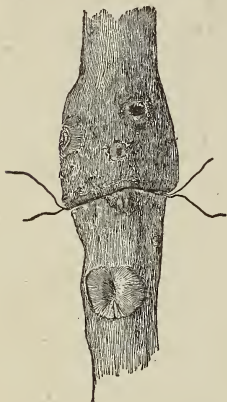


FIG. 118. — TRUNK GIRDLED BY A WIRE. See Fig. 85.

cannot readily pass down and it is stored above the girdle, causing an enlargement.

Assimilation. — *The food from the air and that from the soil unite in the living tissues.* The "sap" that passes upwards from the roots in the growing season is made up largely of the soil water and the salts which have been absorbed in the diluted solutions (p. 67). < This upward-moving water is conducted largely through certain tubular canals of the *young wood*. > These cells are never continuous tubes from root to leaf; but the water passes readily from one cell or canal to another in its upward course.

The upward-moving water gradually passes to the growing parts, and everywhere in the living tissues, it is of

course in the most intimate contact with the soluble carbohydrates and products of photosynthesis. In the building up or reconstructive and other processes it is therefore available. We may properly conceive of certain of the simpler, organic molecules as passing through a series of changes, gradually increasing in complexity. There will be formed substances containing nitrogen in addition to carbon, hydrogen, and oxygen. Others will contain also sulphur and phosphorus, and the various processes may be thought of as culminating in **protoplasm**. *Protoplasm is the living matter in plants.* It is in the cells, and is usually semifluid. Starch is not living matter. The complex process of building up the protoplasm is called **assimilation**.

Respiration. — *Plants need oxygen for respiration, as animals do.* We have seen that plants need the carbon dioxide of the air. To most plants the nitrogen of the air is inert, and serves only to dilute the other elements; but the *oxygen is necessary for all life*. We know that all animals need this oxygen in order to breathe or respire. In fact, they have become accustomed to it in just the proportions found in the air; and this is now best for them. When animals breathe the air once, they make it foul, because they use some of the oxygen and give off carbon dioxide. Likewise, *all living parts of the plant must have a constant supply of oxygen*. Roots also need it, for they respire. Air goes in and out of the soil by diffusion, and as the soil is heated and cooled, it causes the air to expand and contract.

The oxygen passes into the air spaces and is absorbed by the moist cell membranes. In the living cells it makes possible the formation of simpler compounds by which energy is released. This energy enables the plant to

work and grow, and the final products of this action are *carbon dioxide and water*. As a result of the use of this oxygen by night and by day, plants give off carbon dioxide, *Plants respire; but since they are stationary, and more or less inactive, they do not need as much oxygen as animals, and they do not give off so much carbon dioxide.* A few plants in a sleeping room need not disturb one. It should be noted, however, that germinating seeds respire vigorously, hence they consume much oxygen; and opening buds and flowers are likewise active.

Transpiration. *— Much more water is absorbed by the roots than is used in growth, and this surplus water passes from the leaves into the atmosphere by an evaporation process known as transpiration.* Transpiration takes place more abundantly from the under surfaces of leaves through the pores or stomates. *— A sunflower plant of the height of a man, during an active period of growth, gives off a quart of water each day. A large oak tree may transpire 150 gallons each day during the summer. For every ounce of dry matter produced, it is estimated that 15 to 25 pounds of water usually pass through the plant.*

— When the roots fail to supply to the plant sufficient water to equalize that transpired by the leaves, the plant wilts. Transpiration from the leaves and delicate shoots is increased by all of the conditions which increase evaporation, such as higher temperature, dry air, or wind. The stomates open and close, tending to regulate transpiration as the varying conditions of the atmosphere affect the moisture content of the plant. However, in periods of drought or of very hot weather, and especially during a hot wind, the closing of these stomates cannot sufficiently prevent evaporation. The roots may be very active and yet fail to absorb sufficient moisture to equalize that given

off by the leaves. The plant shows the effect (how?). On a hot, dry day, note how the leaves of corn "roll" towards afternoon. Note how fresh and vigorous the same leaves appear early the following morning. Any injury to the roots, such as a bruise, or exposure to heat, drought, or cold may cause the plant to wilt.

Water is forced up by **root pressure** or **sap pressure**. (Page 104.) Some of the dew on the grass in the morning may be the water forced up by the roots; some of it is the condensed vapor of the air.

The wilting of a plant is due to the loss of water from the cells. The cell walls are soft, and collapse. A toy balloon will not stand alone until it is inflated with air or liquid. In the woody parts of the plant cell walls may be stiff enough to support themselves, even though the cell is empty. Measure the contraction due to wilting and drying by tracing a fresh leaf on a page of a notebook, and then tracing the same leaf after it has been dried between papers. The softer the leaf, the greater will be the contraction.

Storage.—We have said that starch may be stored in twigs to be used the following year. The very early flowers on fruit trees, especially those that come before the leaves, and those that come from bulbs, as crocuses and tulips, are supported by the starch or other food that was organized the year before. Some plants have very special, storage reservoirs, as in the case of the potato, which is a thickened stem although growing underground. (Why a thickened stem? p. 84.) It is well to make the starch test on winter twigs and on all kinds of thickened parts, as tubers and bulbs.

Carnivorous Plants.—Certain plants capture insects and other very small animals and utilize them to some extent as food. Such are the sundew, that has on the leaves

sticky hairs that close over the insect; the Venus's flytrap of the Southern states, in which the halves of the leaves



FIG. 119. — THE COMMON PITCHER PLANT (*Sarracenia purpurea*) of the North, showing the tubular leaves and the odd, long-stalked flowers.

close over the prey like the jaws of a steel trap; and the various kinds of pitcher plants that collect insects and other organic matter in deep, water-filled, flask-like leaf pouches (Fig. 119).

The sundew and Venus's fly-trap are sensitive to contact. Other plants are *sensitive to the touch* without being insectivorous. The common, cultivated sensitive plant is an example.

This is readily grown from seeds (sold by seedsmen) in a warm place. Related wild plants in the south are sensitive. The

utility of this sensitiveness is not understood.

Parts that Simulate Leaves. — We have learned that leaves are endlessly modified to suit the conditions in which the plant is placed. The most marked modifications are in adaptation to light. On the other hand, *other organs often perform the functions of leaves*. Green shoots function as leaves. These shoots may look like leaves, in which case they are called **cladophylla**. The foliage of common asparagus is made up of fine branches: the real morphological leaves are the minute dry functionless scales at the bases of these branchlets. (What reason is there for calling them leaves?) The broad "leaves" of the florist's smilax are cladophylla: where are the leaves on this plant? In most of the cacti, the entire plant-body performs the functions of leaves until the parts become cork-bound.

Leaves are sometimes modified to perform other functions than the vital processes: they may be tendrils, as the terminal leaflets of pea and sweet pea; or spines, as in barberry. Not all spines and thorns, however, represent modified leaves: some of them (as of hawthorns, osage orange, honey locust) are branches.

SUGGESTIONS. —

1. *To test for chlorophyll.* Purchase about a gill of wood alcohol. Secure a leaf of geranium, clover, or other plant that has been exposed to sunlight for a few hours, and, after dipping it for a minute in boiling water, put it in a white cup with sufficient alcohol to cover. Place the cup in a shallow pan of hot water on the stove where it is not hot enough for the alcohol to take fire. After a time the chlorophyll is dissolved by the alcohol, which has become an intense green. Save this leaf for the starch experiment (Exercise 2). Without chlorophyll, the plant cannot appropriate the carbon dioxide of the air.

2. *Starch and photosynthesis.* Starch is present in the green leaves which have been exposed to sunlight; but in the dark no starch can be formed from carbon dioxide. Apply iodine to the leaf from which the chlorophyll was dissolved in the previous experiment. Note that the leaf is colored purplish-brown throughout. The leaf contains starch. Secure a leaf from a plant which has been in the darkness for about two days. Dissolve the chlorophyll as before, and attempt to stain this leaf with iodine. No purplish-brown color is produced. This shows that the starch manufactured in the leaf may be entirely removed during darkness. Secure a plant which has been kept in darkness for twenty-four hours or more.



FIG. 120. — EXCLUDING LIGHT AND CO_2 FROM PART OF A LEAF.



FIG. 121. — THE RESULT.

Split a small cork and pin the two halves on opposite sides of one of the leaves, as shown in Fig. 120. Place the plant in the sunlight again. After a morning of bright sunshine dissolve the chlorophyll in this leaf with alcohol; then stain the leaf with the iodine.

Notice that the leaf is stained deeply except where the cork was; there sunlight and carbon dioxide were excluded (Fig. 121). There is no starch in the covered area. Plants or parts of plants that have developed no chlorophyll can form no starch. Secure a variegated leaf of coleus, ribbon grass, geranium, or of any plant showing both white and green areas. On a day of bright sunshine, test one of these leaves by the alcohol and iodine method for the presence of starch. Observe that the parts devoid of green color have formed no starch.

the leaves,
removed,

However, after starch has once been formed in it may be changed into soluble substances and to be converted again into starch in certain other parts of the living tissues.

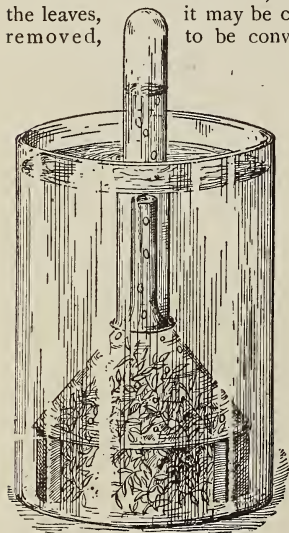


FIG. 122. — TO SHOW THE ESCAPE OF OXYGEN.

3. *To test the giving off of oxygen by day.* Make the experiment illustrated in Fig. 122. Under a funnel in a deep, glass jar containing fresh spring or stream water place fresh pieces of the common waterweed elodea (or anacharis). Have the funnel considerably smaller than the vessel, and support the funnel well up from the bottom so that the plant can more readily get all of the carbon dioxide available in the water. Why would boiled water be undesirable in this experiment? For a home-made glass funnel, crack the bottom off a narrow-necked bottle by pressing a red-hot poker or iron rod against it and leading the crack around the bottle. Invert a test-tube over the stem of the funnel. In sunlight bubbles of oxygen will arise and collect in the test-tube. If a

sufficient quantity of oxygen has collected, a lighted taper inserted in the tube will glow with a brighter flame, showing the presence of oxygen in greater quantity than in the air. Shade the vessel. Are bubbles given off? For many reasons it is impracticable to continue this experiment longer than a few hours. Observe the bubbles on pond scum and waterweeds on a bright day.

4. *To illustrate the results of respiration (CO_2).* In a jar of germinating seeds (Fig. 123) place carefully a small dish of lime-water and cover tightly. Put a similar dish in another jar of about

the same air space. After a few hours compare the cloudiness or precipitate in the two vessels of limewater. Or, place a growing plant in a deep, covered jar away from the light, and after a few hours insert a lighted candle or splinter. Or, perform a similar experiment with fresh roots of beets or turnips (Fig. 124) from which the leaves are mostly removed. In this case, the jar need not be kept dark; why?



FIG. 123.—TO ILLUSTRATE A PRODUCT OF RESPIRATION.

small bottle of water. Invert over this a fruit jar, and observe that a mist soon accumulates on the inside of the glass. In time drops of water form. The experiment may be varied as shown in Fig. 125. Or, invert the fruit jar over an entire plant, as shown in Fig. 126, taking care to cover the soil with oiled paper or rubber cloth to prevent evaporation from the soil. The test may also be made by placing the pot, properly protected, on a balance, and the loss of weight will be noticed (Fig. 127). Cut a winter twig, seal the severed end with wax, and allow

5. *To test transpiration.* Cut a succulent shoot of any plant, thrust the end of it through a hole in a cork, and stand it in a

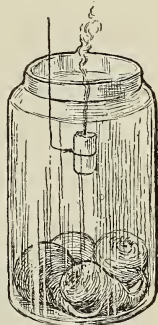


FIG. 124.—RESPIRATION OF THICK ROOTS.

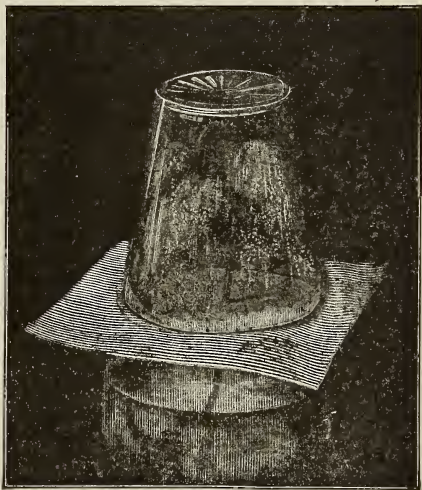


FIG. 125.—TO ILLUSTRATE TRANSPIRATION.

the twig to lie several days ; it shrivels. There must be some upward movement of water even in winter, else plants would shrivel and die.

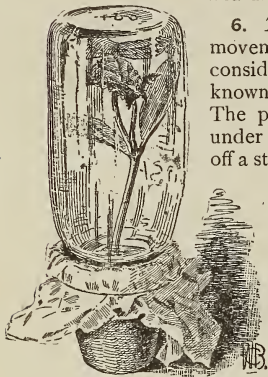


FIG. 126. — TO ILLUSTRATE TRANSPIRATION.

6. *To illustrate sap pressure.* The upward movement of sap water often takes place under considerable force. The cause of this force, known as *root pressure*, is not well understood. The pressure varies with different plants and under different conditions. To illustrate : cut off a strong-growing, small plant near the ground.

By means of a bit of rubber tube attach a glass tube with a bore of approximately the diameter of the stem. Pour in a little water. Observe the rise of the water due to the pressure from below (Fig. 128).

Some plants yield a large amount of water under a pressure sufficient to raise a column several feet ; others force out little, but under considerable pressure (less easily demonstrated).

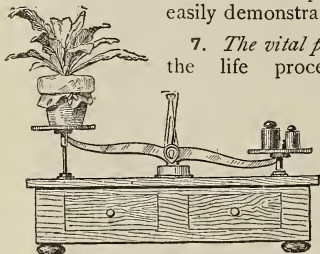


FIG. 127. — LOSS OF WATER.

7. *The vital processes (i.e., the life processes).* The

pupil having studied roots, stems, and leaves, should now be able to describe the main vital functions of plants : (1)

what is the root function? stem function? leaf function? (2) What is meant by the "sap"? (3) Where and how does the plant secure its water? oxygen? carbon? hydrogen? nitrogen? sulphur? potassium? calcium? iron? phosphorus? (4) Where is all the

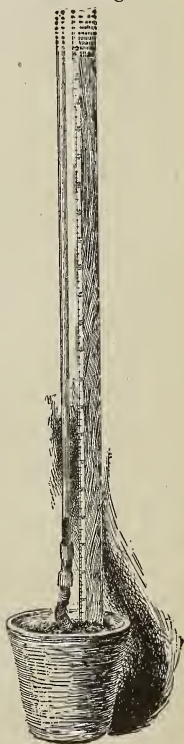


FIG. 128. — TO SHOW SAP PRESSURE.

starch in the world made? What does a starch-factory establishment do? Where are the real starch factories? (5) In what part of the twenty-four hours do plants grow most rapidly in length? When is food formed and stored most rapidly? (6) Why do plants turn yellow in a long rainy spell? (7) If stubble, corn stalks, or wheat straw are burned in the field, is as much plant-food returned to the soil as when they are plowed under? (8) What process of plants is roughly analogous to perspiration of animals? (9) What part of the organic world uses raw matter for food? (10) Is the amount of water transpired equal to the amount absorbed? (11) Give some reasons why plants very close to a house may not thrive or may even die. (12) Why are fruit-trees pruned or thinned out as in Fig. 129?

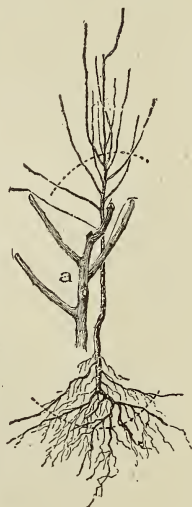


FIG. 129. — AN APPLE TREE, with suggestions as to pruning when it is transplanted. At *a* is shown a pruned top.

8. Proper balance between top and root. We have learned that the leaf parts and the root parts work together. They may be said to balance each other in activities, the root supplying the top and the top supplying the root (how?). If half the roots were cut from a tree, we should expect to reduce the top also, particularly if the tree is being transplanted. How and why would you prune a tree or bush that is being transplanted? Fig. 129 may be suggestive.



FIG. 130. — BEFORE AND AFTER PRUNING.

CHAPTER XIV

DEPENDENT PLANTS

THUS far we have spoken of plants with roots and foliage and that depend on themselves. They collect the raw materials and make them over into assimilable food. They are **independent**. Plants without green foliage can-



FIG. 131. — A MUSHROOM, example of a saprophytic plant. This is the edible, cultivated mushroom.

not make food; they must have it made for them or they die. They are **dependent**. A sprout from a potato tuber in a dark cellar cannot collect and elaborate carbon dioxide. It lives on the food stored in the tuber.

All plants with naturally white or blanched parts are dependent. Their leaves do not develop. They live on organic matter—that which has been made by a plant or elaborated by an animal. The dodder, Indian pipe, and coral root among flower-bearing plants, also mushrooms and other fungi (Figs. 131, 132) are examples. The dodder is common in swales, being conspicuous late in the season from its thread-like yellow or orange stems spreading over the herbage of other plants. One kind attacks alfalfa and is a bad pest. The seeds germinate in the spring, but as soon as the twining stem at-

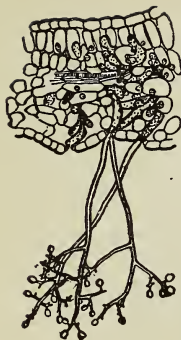


FIG. 132. — A PARASITIC FUNGUS, magnified.

The mycelium, or vegetative part, is shown by the dotted-shaded parts ramifying in the leaf tissue. The rounded haustoria projecting into the cells are also shown. The long fruiting parts of the fungus hang from the under surface of the leaf.

taches itself to another plant, the dodder dies away at the base and becomes wholly dependent. It produces flowers in clusters and seeds itself freely (Fig. 133).

Parasites and Saprophytes. — A plant that is dependent on a living plant or animal is a **parasite**, and the plant or animal on which it lives is the **host**. The dodder is a true parasite; so are the rusts, mildews, and other fungi that attack leaves and shoots and injure them.

The threads of a parasitic fungus usually creep through the intercellular spaces in the leaf or stem and send suckers (or haustoria) into the cells (Fig. 132). The threads (or the hyphæ) clog the air-spaces of the leaf and often plug the stomates, and they also appropriate and disorganize the cell fluids; *thus they injure or kill their host*. The mass of hyphæ of a fungus is called **mycelium**. Some of the hyphæ finally grow out of the leaf and produce spores or reproductive cells that answer the purpose of seeds in distributing the plant (*b*, Fig. 132).

A plant that lives on dead or decaying matter is a **saprophyte**. Mushrooms (Fig. 131) are examples; they live on the decaying matter in the soil. Mold on bread and cheese is an

The threads of a parasitic fungus usually creep through the intercellular spaces in the leaf or stem and send suckers (or haustoria) into the cells (Fig. 132). The threads (or the hyphæ) clog the air-spaces of the leaf and often plug the stomates, and they also appropriate and disorganize the cell fluids; *thus*

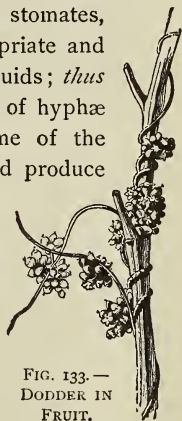


FIG. 133. — DODDER IN FRUIT.

example. Lay a piece of moist bread on a plate and invert a tumbler over it. In a few days it will be moldy. The spores were in the air, or perhaps they had already fallen on the bread, but had not had opportunity to grow. Most green plants are unable to make any direct use of the humus or vegetable mold in the soil, for they are not

saprophytic. The shelf-fungi (Fig. 134) are saprophytes. They are common on logs and trees. Some of them are perhaps partially parasitic, extending the mycelium into the wood of the living tree and causing it to become black-hearted (Fig. 134).

Some parasites spring from the ground, as other plants do, but they are *parasitic on the roots of their hosts*. Some parasites may be *partially parasitic* and *partially saprophytic*. Many (perhaps most) of these ground saprophytes are aided in securing their

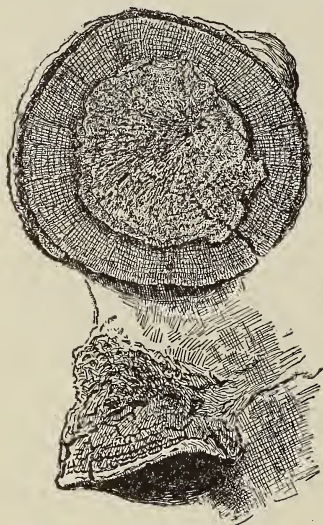


FIG. 134. — TINDER FUNGUS (*Polyporus igniarius*) on beech log. The external part of the fungus is shown below; the heart-rot injury above.

food by soil fungi, which spread their delicate threads over the root-like branches of the plant and act as intermediaries between the food and the saprophyte. These fungus-covered roots are known as **mycorrhizas** (meaning "fungus root"). Mycorrhizas are not peculiar to saprophytes. They are found on many wholly independent plants, as,

for example, the heaths, oaks, apples, and pines. It is probable that the fungous threads perform some of the offices of root-hairs to the host. On the other hand, the fungus obtains some nourishment from the host. The association seems to be mutual.

Saprophytes break down or decompose organic substances. Chief of these saprophytes are many microscopic organisms known as bacteria (Fig. 135). These innumerable organisms are immersed in water or in dead animals and

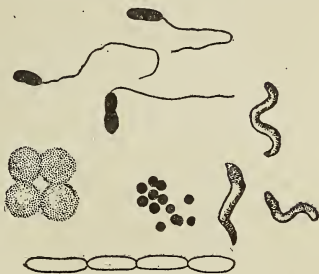


FIG. 135.—BACTERIA OF SEVERAL FORMS, much magnified.



FIG. 136.—THE INDIAN PIPE,
A SAPROPHYTE.

plants, and in all manner of moist organic products. By breaking down organic combinations, *they produce decay*. Largely through their agency, and that of many true but microscopic fungi, *all things pass into soil and gas*. Thus are the bodies of plants and animals removed and the continuing round of life is maintained.

Some parasites are green-leaved. Such is the mistletoe. They anchor themselves on the host and absorb its juices, but they also appropriate and use the carbon dioxide of the air. We have no plants which are representative of this class.

Epiphytes.—To be distinguished from the dependent

plants are those that grow on other plants without taking food from them. These are green-leaved plants whose roots burrow in the bark of the host plant and perhaps derive some food from it, but which subsist chiefly on materials that they secure from air dust, rain water, and the air. These plants are **epiphytes** (meaning "upon plants") or air plants.

Epiphytes abound in the tropics. Certain orchids are among the best known examples (Fig. 37). The Spanish moss or tillandsia of the South is another. Mosses and lichens that grow on trees and fences may also be called epiphytes. In the struggle for existence, the plants probably *have been driven to these special places* in which to find opportunity to grow. Plants grow where they must, not where they will.

SUGGESTIONS. —

1. In what locations are mushrooms and toadstools usually found? (There is really no distinction between mushrooms and toadstools. They are all mushrooms.)
2. What kinds of mildew, blight, and rust do you know?
3. How do farmers overcome smut in wheat? Explain the reason. Or any other fungous "plant disease"? How do these things injure plants?
4. What is a plant disease? The pupil should know that every spot or injury on a leaf or stem is caused by something, — as an insect, a fungus, wind, hail, drought, or other agency. How many uninjured or perfect leaves are there on the plant growing nearest the schoolhouse steps?
5. Give formula for Bordeaux mixture and tell how and for what it is used. Why does the farmer bluestone his wheat?

CHAPTER XV

WINTER AND DORMANT BUDS

A bud is a growing point, terminating an axis either long or short, or being the starting point of an axis. *All branches spring from buds.* In the growing season the bud is active; later in the season it ceases to increase the axis in length, and as winter approaches the growing point becomes more or less thickened and covered by protecting scales, in preparation for the long resting season. This resting, dormant, or winter body is what is commonly spoken of as a "bud." A winter bud may be defined as an *inactive covered growing point*, waiting for spring.

Structurally, a dormant bud is a shortened axis or branch, bearing miniature leaves or flowers or both, and protected by a covering. Cut in two, lengthwise, a bud of the balm of Gilead or other plant that has large buds. With a pin separate

the tiny leaves. Count them. Examine the big bud of the rhubarb as it lies under the ground in late winter or early spring; or the crown buds of any early spring plants. *The bud is protected by firm and dry scales.* These scales are modified leaves.



FIG. 137. — A BUD cut lengthwise, showing the miniature leaves and the growing point.



FIG. 138. — OPENING OF LEAF BUD.

The scales fit close. Often the bud is protected by varnish (see the balsam poplars). Most winter buds are more or

less woolly. Examine them under a lens. As we might expect, bud coverings are most prominent in cold and dry climates. Sprinkle water on velvet or flannel, and note the result and give a reason.

All winter buds give rise to branches, *not to leaves alone* ; that is, the leaves are borne on the lengthening axis. Sometimes the axis, or branch, remains very short,—so short that it may not be noticed. Sometimes it grows several feet long.

Whether the branch grows large or not depends on the chance it has,—position on the plant, soil, rainfall, and many other factors. The new shoot is the unfolding and enlarging of the tiny axis and leaves that we saw in the bud. If the conditions are congenial, the shoot may form more leaves than were tucked away in the bud. The length of the shoot usually depends more on the lengths of the internodes than on the number of leaves.



FIG. 139. — LEAF-SCARS.

Where Buds are. — *Buds are borne in the axils of the leaves,*—in the acute angle that the leaf makes with the stem. When the leaf is growing in the summer, a bud is forming above it. Sometimes, as in the Manitoba maple, the base of the leaf stalk surrounds the bud and hides it while the leaf remains on the plant. When the leaf falls, the bud remains, and a scar marks the place of the leaf. Fig. 139 shows the large leaf-scars with the small buds just above them. Observe those on the maple, elm, poplar, basswood, or any other tree or bush.

Sometimes two or more buds are borne in one axil ; the extra ones are **accessory** or **supernumerary** buds. Observe them in the Tartarian honeysuckle (common in yards).

If the bud is at the end of a shoot, however short the shoot, it is called a **terminal bud**. *It continues the growth of the axis in a direct line.* Very often three or more buds are clustered at the tip (Fig. 140); and in this case there may be more buds than leaf scars. Only one of them, however, is strictly terminal.

A bud in the axil of a leaf is an **axillary** or **lateral bud**. Note that there is normally at least one bud in the axil of every leaf on a tree or shrub in late summer and fall. The axillary buds, if they grow, are the *starting points of new shoots the following season*. If a leaf is pulled off early in summer, what will become of the young bud in its axil? Try this.



FIG. 140. — TERMINAL BUD BETWEEN TWO OTHER BUDS. — Currant.

Bulbs, as in the lily or onion, and cabbage heads may be likened to buds; that is, they are condensed stems, with

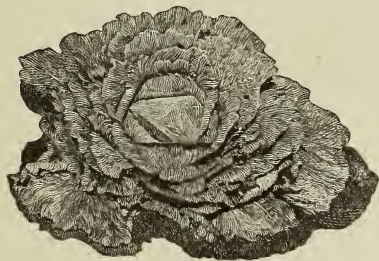


FIG. 141. — A GIGANTIC BUD. — Cabbage.

scales or modified leaves densely overlapping and forming a rounded body (Fig. 141). They differ from true buds, however, in the fact that they are condensations of whole main stems rather than embryo stems

borne in the axils of leaves. But bulblets (as of tiger lily) may be scarcely distinguishable from buds on the one hand and from bulbs on the other. Cut a cabbage head in two, lengthwise, and note what it is like.

The buds that appear on roots are unusual or abnormal, — they occur only occasionally and in no definite order. Buds appearing in unusual places on any part of the plant are called **adventitious buds**. Such usually are the buds that arise when a large limb is cut off, and from which suckers or water sprouts arise.

How Buds Open. — *When the bud swells, the scales are pushed apart, the little axis elongates and pushes out.* In most plants the outside scales fall very soon, leaving a little ring of scars. With terminal buds, this ring marks the end of the year's growth: how? Notice cherry, plum, willow, and other plants. In some others, all the scales grow for a time, while in other plants the inner bud scales become green and almost leaf-like. Examine opening buds of all the trees in your locality.



FIG. 142. — A BUD, showing both leaves and flowers.

Sometimes Flowers come out of the Buds. — Leaves may or may not accompany the flowers. (See Fig. 142.)

Buds that contain or produce only leaves are **leaf-buds**. Those which contain only flowers are **flower-buds** or **fruit-buds**. The latter occur on plum, poplar, willow, and many very early spring-flowering plants. Those that contain both leaves and flowers are **mixed buds**, as in cherry, saskatoon, and most late spring-flowering plants.

Fruit buds are usually thicker or stouter than leaf-buds. They are borne in different positions on different plants. In the wild plum they are on the two-year-old shoots, on some others they are on the last year's growth. Examine the flowers on any trees in your locality and see the age of the wood on which flowers are borne. See also if they are on special short branches or spurs.

"*The burst of spring*" means in large part the opening of the buds. *Everything was made ready the fall before. The embryo shoots and flowers were tucked away, and the food was stored.* The warm rain falls, and the shutters open and the sleepers wake: the frogs peep and the birds come.

Arrangement of Buds. — We have found that leaves are usually arranged in a definite order; buds are borne in the axils of leaves: therefore *buds must exhibit phyllotaxy.* Moreover, branches grow from buds: branches, therefore, should show a definite arrangement; usually, however, they



FIG. 143.— OAK SPRAY. How are the leaves borne with reference to the annual growths?

do not show this arrangement because *not all the buds grow and not all the branches live.* (See Chaps. II and III.) It is apparent, however, that the mode of arrangement of buds determines to some extent the form of the tree: compare bud arrangement in spruce with that in maple or oak.

The uppermost buds on any twig, if they are well matured, are usually the larger and stronger and they are the most likely to grow the next spring; therefore, branches

tend to be arranged in tiers (particularly well marked in spruces and firs). See Fig. 143 and explain it.

Winter Buds show what has been the Effect of Sunlight. —

Buds are borne in the axils of the leaves, and *the size or vigor of the leaf determines to a large extent the size of the bud*. Notice that, in most instances, *the largest buds are nearest the tip*. If the largest ones are not near the tip, there is some special reason for it. Can you state it? Examine the shoots on trees and bushes.

SUGGESTIONS. —

1. Some of the best of all observation lessons are those made on dormant twigs. There are many things to be learned, the eyes are trained, and the specimens are everywhere accessible. At whatever time of year the pupil takes up the study of branches, he should look for three things: the ages of the various parts, the relative positions of the buds and leaves, the different sizes of similar or comparable buds. The best time for this study is just before the buds begin to open in the spring; then he should watch the development of the buds in the axils, and he should determine whether the strength or size of the bud is in any way related to the size and vigor of the subtending (or supporting) leaf. The sizes of buds should also be noted on leafless twigs, and the sizes of the former leaves may be inferred from the size of the leaf-scar below the bud. The pupil should keep in mind the fact of the struggle for food and light, and its effects on the developing buds.

2. *The bud and the branch.* A typical twig in early spring is shown in Fig. 144. The most hasty observation shows that it has various parts, or members. It seems to be divided at the point *f* into two parts. It is evident that the part from *f* to *h* grew last year, and that the part below *f* grew two years ago. The buds on the two parts are very unlike, and these differences challenge investigation. — In order to understand this seemingly lifeless twig, it will be necessary to see it as it looked late last summer (and this condition is shown in Fig. 145). The part from *f* to *h*, — which has just completed its growth, — is seen to have its leaves growing singly. In every axil (or angle which the leaf makes when it joins the shoot) is a bud. The leaf starts first, and as the season advances the bud forms in its axil. When the leaves have fallen, at the approach of winter, the buds remain, as seen in Fig. 144.

Every bud on the last year's growth of a winter twig, therefore, marks the position occupied by a leaf when the shoot was grow-



FIG. 144.—AN
APPLE TWIG.



FIG. 145:—Same twig before leaves fell.

ing.—The part below *f*, in Fig. 145, shows a wholly different arrangement. The leaves are two or more together (*aaaa*), and

there are buds without leaves (*bbbb*). A year ago this part looked like the present shoot from *f* to *h*, — that is, the leaves were single, with a bud in the axil of each. It is now seen that some of these bud-like parts are longer than others, and that the longest ones are those which have leaves. It must be because of the leaves that they have increased in length. The body *c* has lost its leaves through some accident, and its growth has ceased. In other words, the parts at *aaaa* are like the shoot *fh*, except that they are shorter, and they are of the same age. One grew from the end or terminal bud of the main branch, and the others from the side or lateral buds. Parts or bodies that bear leaves are, therefore, branches. — The buds at *bbbbbb* have no leaves, and they remain the same size that they were a year ago. They are dormant. The only way for a mature bud to grow is by making leaves for itself, for a leaf will never stand below it again. The twig, therefore, has buds of two ages, — those at *bbbb* are two seasons old, and those on the tips, of all the branches (*aaaa*, *h*), and in the axil of every leaf, are one season old. It is only the terminal buds that are not axillary. When the bud begins to grow and to put forth leaves, it gives rise to a branch, which, in its turn, bears buds. — It will now be interesting to determine why certain buds gave rise to branches and why others remained dormant. The strongest shoot or branch of the year is the terminal one (*fh*). The next in strength is the uppermost lateral one, and the weakest shoot is at the base of the twig. The dormant buds are on the under side (for the twig grew in a horizontal position). All this suggests that those buds grew which had the best chance, — the most sunlight and room. There were too many buds for the space, and in the struggle for existence those that had the best opportunities made the largest growths. This struggle for existence began a year ago, however, when the buds on the shoot below *f* were forming in the axils of the leaves, for the buds near the tip of the shoot grew larger and stronger than those near its base. The growth of one year, therefore, is very largely determined by the conditions under which the buds were formed the previous year.

3. The balm of Gilead or balsam poplar has large buds which are good for class purposes. Twigs of any trees kept in a vase in the winter or early spring will furnish good class room material.

April 17.

CHAPTER XVI

BUD PROPAGATION

WE have learned (in Chap. VI) that plants propagate by means of seeds. *They also propagate by means of bud parts, — as rootstocks (rhizomes), roots, runners, layers, bulbs.* The pupil should determine how any plant in which he is interested naturally propagates itself (or spreads its kind). Determine this for raspberry, strawberry, June-grass or other grass, blueberry, quack grass, currant, gooseberry, onion, Russian thistle, mustard, tiger lily, geranium, clover, alfalfa, burdock, Irish potato, cotton, pea, corn, wheat.

Plants may be *artificially propagated* by similar means, as by *cuttings, layers, and grafts*. The last two we need not discuss here, as they are but little used except in fruit-growing regions.

Cuttings in General. — *A bit of a plant stuck into the ground stands a chance of growing; and this bit is a cutting.* Plants have preferences, however, as to the kind of a bit which shall be used, but *there is no way of telling what this preference is except by trying.* In some instances this preference has not been discovered, and we say that the plant cannot be propagated by cuttings.

Most plants prefer that the cutting be made of the **soft** or **growing parts** (called “wood” by gardeners), of which the “slips” of geranium and coleus are examples. Others grow equally well from cuttings of the **hard** or **mature parts** or **wood**, as in willow, Virginia creeper, balm of Gilead, cottonwood, red osier, dogwood, currant, and gooseberry. In some cases cuttings are made of tubers, as in the Irish

potato (Fig. 60). Pupils should make cuttings now and then. If they can do nothing more, they can make cuttings of potato, as the farmer does; and they can plant them in a box in the window.

The Softwood Cutting. — The softwood cutting is made from tissue that is still growing, or at least from that which is not dormant. *It comprises one or two joints, with*



FIG. 146. — GERANIUM CUTTING.



FIG. 147. — COLEUS CUTTING
BEING ROOTED IN WATER.

a leaf attached (Figs. 146, 147). It must not be allowed to wilt. Therefore, it must be *protected from direct sunlight and dry air until it is well established*; and if it has many leaves, some of them should be removed, or at least cut in two, in order to reduce the evaporating surface. The soil should be uniformly moist. The coleus grows better if rooted in water before transplanting (Fig. 147).

For most plants, the proper age or maturity of wood for the making of cuttings may be determined by giving the twig a quick bend: if it snaps and hangs by the bark, it is in proper condition; if it bends without breaking, it is too young and soft or too old; if it splinters, it is too old and woody. The tips of strong upright shoots usually make the best cuttings. Preferably, each cutting should have a joint or node near its base; and if the internodes are very short, it may comprise two or three joints.

The stem of the cutting is inserted one third or more its length in clean sand or gravel, and the earth is pressed firmly about it. A newspaper may be laid over the bed to exclude the light—if the sun strikes it—and to prevent too rapid evaporation. The soil should be moist clear through, not on top only.

Loose sandy or gravelly soil is used. Sand used by masons is good material in which to start most cuttings; or fine gravel—sifted of most of its earthy matter—may be used. Soils are avoided which contain much decaying organic matter, for these soils are breeding places of fungi, which attack the soft cutting and cause it to “damp

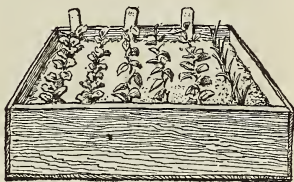


FIG. 148. — CUTTING-BOX.

off,” or to die at or near the surface of the ground. If the cuttings are to be grown in a window, put three or four inches of the earth in a shallow box or a pan. A soap box cut in two lengthwise, so that it makes a box four or five inches deep—as a gardener’s flat—is excellent (Fig. 148). Cuttings of common plants, as geranium, coleus,



FIG. 149. — VERBENA CUTTING READY FOR TRANSPLANTING.

fuchsia, carnation, are kept at a living-room temperature. As long as the cuttings look bright and green, they are in good condition. It may be a month before roots form. When roots have formed, the plants begin to make new leaves at the tip. Then they may be transplanted into other boxes

or into pots. The verbena in Fig. 149 is just ready for transplanting.

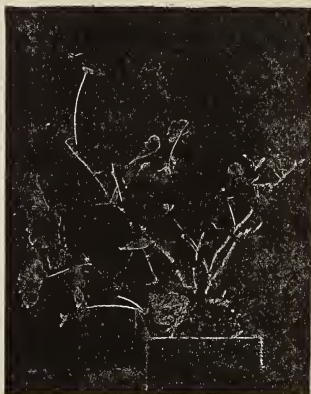


FIG. 150.—OLD GERANIUM PLANT CUT BACK TO MAKE IT THROW OUT SHOOTS FROM WHICH CUTTINGS CAN BE MADE.

It is not always easy to find growing shoots from which to make the cuttings. The best practice, in that case, is to cut back an old plant, then keep it warm and well watered, and thereby force it to throw out new shoots. The old geranium plant from the window garden, or the one taken up from the lawn bed, may be treated this way (see Fig. 150). The best plants of geranium and coleus and most window plants are those which are not more than one year old. *The geranium and fuchsia cuttings which are made in January, February, or March will give compact blooming plants for the next winter; and thereafter new ones should take their places* (Fig. 151).

The Hardwood Cutting.—*Best results with cuttings of mature wood are*



FIG. 151.—EARLY WINTER GERANIUM, from a spring cutting.

secured when the cuttings are made in the fall and then buried until spring in sand in the cellar. These cuttings are usually six to ten inches long. They are not idle while they rest. The lower end calluses or heals, and the roots form more readily when the cutting is planted in the spring. But if the proper season has passed, take cuttings at any time in winter, plant them in a deep box in the window, and watch. They will need no shading or special care. Grape, currant, gooseberry, willow, and poplar readily take root from the hardwood. Fig. 152 shows a currant cutting. It has only one bud above the ground.

Grafting, budding, and layering are methods of propagation largely used in fruit-growing regions. The graft is in reality a cutting planted in the stem of another plant. If the cutting is a bud, the process is called budding.

In some plants if the lower branches are fastened down to the ground, they take root. The branch may then be cut off and a new plant is started. This process is known as layering and is largely used in propagating roses, currants, and gooseberries. So far little or no use has been made of these methods of propagation in our climate. Budding is mostly restricted to young trees in the nursery. In the spring following the budding, the stock is cut off just above the bud, so that only the shoot from the bud grows to make the future tree. This prevailing form of budding is known as shield-budding.



FIG. 152. — CURRANT CUTTING.

SUGGESTIONS. —

1. Name the plants that the gardener propagates by means of cuttings. Start cuttings of both woody and herbaceous plants. The cutting-box may be set in the window. If the box does not receive direct sunlight, it may be covered with a pane of glass to prevent evaporation. Take care that the air is not kept too close, else the damping-off fungi may attack the cuttings, and they will rot at the surface of the ground. See that the pane is raised a little at one end to afford ventilation; and if the water collects in drops on the under side of the glass, remove the pane for a time.

2. What is a generation of a tree grown from a cutting?

CHAPTER XVII

HOW PLANTS CLIMB

WE have found that plants struggle or contend for a place in which to live. Some of them become adapted to grow in the forest shade, others to grow on other plants, as epiphytes, others to *climb to the light*. Observe how woods grapes, and other forest climbers, spread their foliage on the very top of the forest tree, while their long, flexile trunks may be bare.

There are several ways by which plants climb, but most climbers may be classified into four groups: (1) **scramblers**, (2) **root climbers**, (3) **tendrils climbers**, (4) **twiners**.

Scramblers. — Some plants rise to light and air *by resting their long and weak stems on the tops of bushes and quick-growing herbs*. Their stems may be elevated in part by the growing twigs of the plants on which they recline. Such plants are scramblers. Usually they are provided with prickles or bristles. The bedstraw or galium, except the northern bedstraw, is a scrambler frequently found in moist places.

Root Climbers. — Some plants climb by means of *true roots*. These roots seek the dark places and therefore enter the chinks in walls and bark. The true or English ivy, which is often grown as a house plant or in milder climates used to cover buildings, is another instance, and sometimes poison ivy. Roots are distinguished from stem tendrils by their *irregular or indefinite position* as well as by their mode of growth.

Tendrils Climbers. — A slender coiling part that serves to hold a climbing plant to a support is known as a **tendrils**.



FIG. 153. — TENDRIL, to show where the coil is changed.

The free end swings or curves until it strikes some object, when it attaches itself and then coils and *draws the plant close to the support*. The spring of the coil also allows the plant *to move in the wind*, thereby enabling the

plant to maintain its hold. Slowly pull a well-matured tendril from its support, and note how strongly it holds on. Watch the tendrils in a wind-storm. Usually the tendril attaches to the support by *coiling about it*, as in a pea, grape, and Virginia creeper (Fig. 154), but in some plants they attach to walls by means of *disks* on the ends of the tendrils.

Since both ends of the tendril are fixed, when it finds a support, the coiling would tend to twist it in two. It will be found, however, that the tendril *coils in different directions* in different

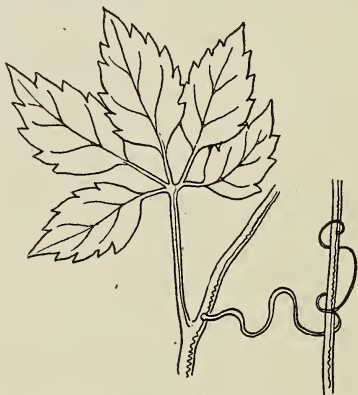


FIG. 154. — TENDRIL OF VIRGINIA CREEPER.

parts of its length. In Fig. 153, showing an old and stretched-out tendril, the change of direction in the coil occurred at *a*. In long tendrils of cucumbers and melons there may be several changes of direction.

Tendrils may represent either *branches* or *leaves*. In the

Virginia creeper and grape they are branches ; they stand opposite the leaves in the position of fruit clusters, and sometimes one branch of a fruit-cluster is a tendril. These tendrils are therefore homologous with fruit-clusters, and fruit-clusters are branches.

In some plants tendrils are *leaflets* (Chap. XI). Examples are the sweet pea and the common wild peas. In Fig. 155, observe the leaf with its two great stipules, petiole, six normal leaflets, and two or three pairs of leaflet tendrils and a terminal leaflet tendril. In some plants, as in the carrion flower or wild smilax, common around the edges of groves, the stipules form tendrils.

The *petiole* or *midrib* may act as a *tendril*, as in various kinds of clematis. In Fig. 156, the wild clematis of the prairie region, this mode is seen.

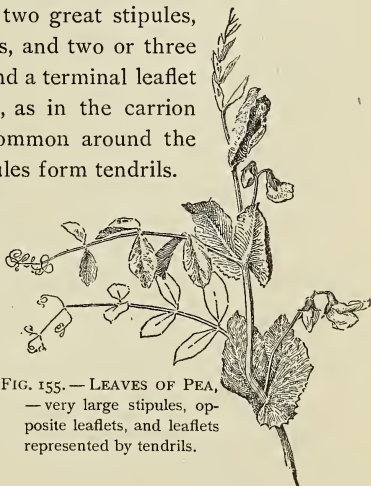


FIG. 155. — LEAVES OF PEA,
— very large stipules, op-
posite leaflets, and leaflets
represented by tendrils.

Twiners. — The entire plant or shoot may wind about a support, Such a plant is a **twiner**. Ex-

amples are the garden bean, wild hop, morning-glory, wild buckwheat or black bindweed, bittersweet or waxwork (*Celastrus*), some honeysuckles, and dodder. The free tip of the twining branch *sweeps about in curves*, much as the tendril does, until it finds support or becomes old and rigid.

Each kind of plant usually coils *in only one direction*. Most plants coil against the sun, or from the observer's left across his front to his right as he faces the plant. Examples are bean, morning-glory. The hop twines from the observer's right to his left, or with the sun.



FIG. 156.—CLEMATIS CLIMBING BY LEAF-TENDRIL.

SUGGESTIONS. —

1. Set the pupil to watch the behavior of any plant that has tendrils at different stages of maturity. A vigorous cucumber plant is one of the best. Just beyond the point of a young, straight tendril set a stake to compare the position of it. Note whether the tendril changes position from hour to hour or day to day. Is the tip of the tendril perfectly straight? Why? Set a small stake at the end of a strong straight tendril, so the tendril will just reach it. Watch, and make drawing. If a tendril does not find a support, what does it do? To test the movement of a free tendril, draw an ink line lengthwise of it, and note whether the line remains always on the concave side or the convex side. Name the tendril-bearing plants that you know.

2. Make similar observations and experiments on the tips of twining stems. What twining plants do you know, and which way do they twine?

3. How does any plant that you know get up in the world? Does the stem of a climbing plant contain more or less substance (weight) than an erect self-supporting stem of the same height? Explain.

CHAPTER XVIII

THE FLOWER—ITS PARTS AND FORMS

THE function of the flower is to *produce seed*. It is probable that all its varied forms and colors contribute to this supreme end. These forms and colors please the human fancy and add to the joy of living, but the flower exists for the good of the plant, not for the good of man. The parts of the flower are of two general kinds—those that are directly concerned in the *production of seeds*, and those that act as *covering and protecting organs*. The former parts are known as the **essential organs**; the latter as the **floral envelopes**.

Envelopes.—The floral envelopes usually bear a close resemblance to leaves. These envelopes are very commonly of two series or kinds—the *outer* and the *inner*. The outer series, known as the **calyx**, is usually smaller and green. It usually comprises the outer cover of the flower bud. The calyx is the lowest whorl in Fig. 157.

The inner series, known as the **corolla**, is usually colored and more special or irregular in shape than the calyx. It is the showy part of the flower, as a rule. The corolla is the second or large whorl in Fig. 157.

The *calyx* may be composed of several leaves. Each leaf is a **sepal**. If it is of one piece, it may be lobed or divided, in which case the divisions are called **calyx-lobes**.



FIG. 157.—FLOWER OF A BUTTERCUP IN SECTION.

In like manner, the corolla may be composed of **petals**, or it may be of one piece and variously lobed. A calyx of one piece, no matter how deeply lobed, is **gamosepalous**. A corolla of one piece is **gamopetalous**. When these series are of separate pieces, as in Fig. 157, the flower is said to be **polysepalous** and **polypetalous**. Sometimes both



FIG. 158. — FLOWER OF
FUCHSIA IN SECTION.

series are of separate parts, and sometimes only one of them is so formed.

The floral envelopes are homologous with leaves. Sepals and petals, at least when more than three or five, are in more than one whorl, and one whorl stands below another so that the parts overlap. They are borne on the expanded or thickened end of the flower stalk; this end is the **torus**. In Fig. 157 all the parts are seen as attached to the torus. This part is sometimes called the *re-*

ceptacle, but this word is a common-language term of several meanings, whereas torus has no other meaning. Sometimes one part is attached to another part, as in the fuchsia (Fig. 158), in which the petals are borne on the calyx-tube.

Subtending Parts. — Sometimes there are *leaf-like parts just below the calyx*, looking like a second calyx. Such parts accompany the carnation flower. These parts are **bracts** (bracts are small specialized leaves); and they form an **involucre**. We must be careful that we do not mistake them for true flower parts. Sometimes the bracts are large and petal-like, as in the great white blooms of the

bunch berry or flowering dogwood: here the real flowers are small and greenish, forming a cluster in the centre.

Essential Organs. — The essential organs are of two series. The outer series is composed of the **stamens**. The inner series is composed of the **pistils**.

Stamens bear the **pollen**, which is made up of grains or spores, each spore usually being a single plant cell. The stamen is of two parts, as is readily seen in Figs. 157, 158, — the enlarged terminal part or **anther**, and the stalk or **filament**. The filament is often so short as to seem to be absent, and the anther is then said to be *sessile*. The anther bears the pollen spores. It is made up of two or four parts (known as **sporangia** or **spore-cases**), which burst and discharge the pollen. *When the pollen is shed, the stamen dies.*

The *pistil* has three parts: the lowest, or seed-bearing part, which is the **ovary**; the **stigma** at the upper extremity, which is a flattened or expanded surface, and usually roughened or sticky; the stalk-like part or **style**, connecting the ovary and stigma.

Sometimes the style is apparently wanting, and the stigma is said to be *sessile* on the ovary. These parts are shown in the fuchsia (Fig. 158). The ovary or seed vessel is at *a*. A long style, bearing a large stigma, projects from the flower. See also Fig. 159.

Stamens and pistils probably are homologous with leaves. A pistil is sometimes conceived to represent anciently a

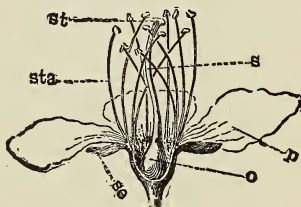


FIG. 159. — THE STRUCTURE OF A PLUM BLOSSOM.

se, sepals; *p*, petals; *sta*, stamens; *o*, ovary; *s*, style; *st*, stigma. The pistil consists of the ovary, style, and stigma. It contains the seed part. The stamens are tipped with anthers, in which the pollen is borne. The ovary, *o*, ripens into the fruit.

leaf as if rolled into a tube; and an anther, a leaf of which the edges may have been turned in on the midrib.



FIG. 160.—SIMPLE PISTILS OF BUTTERCUP, one in longitudinal section.

The pistil may be of *one part or compartment, or of many parts*. The different units or parts of which it is composed are **carpels**. Each carpel is homologous with a leaf. Each carpel bears one or more seeds. A pistil of one carpel is **simple**; of two or more carpels, **compound**. Usually the structure of the pistil may be de-

termined by cutting horizontally across the lower or seed-bearing part, as Figs. 161, 162 explain. A flower may contain a simple pistil (one carpel), as the pea (Fig. 161); *several simple pistils* (several separate carpels), as the buttercup (Fig. 160); or a *compound pistil* with carpels united, as in the diagram (Fig. 162). How many carpels in an apple? A plum? A pea pod? A bean pod? The seed cavity in each carpel is called a **locule** (Latin *locus*, a place). In these locules *the seeds are borne*.



FIG. 161.—PISTIL OF GARDEN PEA, the stamens being pulled down in order to disclose it; also a section showing the single compartment (compare Fig. 188).

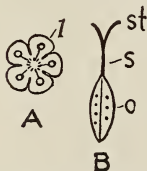


FIG. 162.—DIAGRAM OF A COMPOUND PISTIL.

A, cross-section of the ovary;
B, longitudinal section showing: *st*, stigma; *s*, style; *o*, ovary.

Conformation of the Flower.—A flower that has calyx, corolla, stamens, and pistils is said to be **complete** (Fig. 157); all others are **incomplete**. In some flowers both the floral envelopes are wanting: such are **naked**. When one of the floral envelope series is wanting, the remaining series is said to be calyx, and the flower is therefore **apetalous** (without petals). The knot-

weed (Fig. 163), early anemone, maple, and elm are examples.

Some flowers lack the pistils: these are **staminate**, whether the envelopes are missing or not.

Others lack the stamens: these are **pistillate**.

Others have neither stamens nor pistils: these are **sterile** (outer row in cranberry). Those

that have both stamens and pistils are **perfect**, whether or not the envelopes are missing.

Those that lack either stamens or pistils are **imperfect** or **diclinous**.

Staminate and pistillate flowers are imperfect or diclinous.

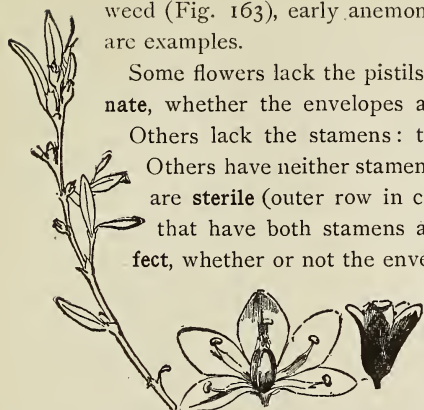


FIG. 163 — KNOTWEED, a very common but inconspicuous plant along hard walks and roads. Two flowers, enlarged, are shown at the right. These flowers are very small and borne in the axils of the leaves.

When staminate and pistillate flowers are borne on the same plant, *e.g.* oak (Fig. 164), corn, cucumber, hazel, pine, begonia (Fig. 165), watermelon, gourd, pumpkin,



FIG. 164. — STAMINATE CATKINS OF OAK. The pistillate flowers are in the leaf axils, and not shown in this picture.

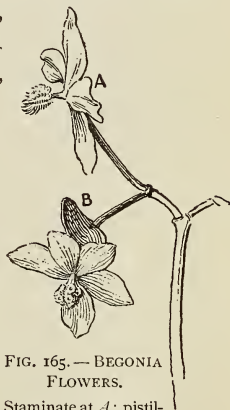


FIG. 165. — BEGONIA FLOWERS.

Staminate at A; pistillate below, with the winged ovary at B.

the plant is **monœcious** ("in one house"). When they are on different plants, *e.g.* poplar, cottonwood, maple, willow



FIG. 166. — CATKINS OF A WILLOW.

A staminate flower is shown at *s*, and a pistillate flower at *p*. The staminate and pistillate are on different plants.

(Fig. 166), the plant is **diœcious** ("in two houses"). Some varieties of strawberry and other plants are partly dioecious. Is the rose either monœcious or diœcious?

Flowers in which the parts of each series are alike are said to be **regular** (as in Figs. 157, 158, 159). Those in which some parts are unlike other parts of the same series

are **irregular**. Their regularity may be in calyx, as in nasturtium (Fig. 167); in corolla (Fig. 168); in the stamens, as in shepherd's purse (Fig. 185); or even pistils. Irregularity is most frequent in the corolla.



FIG. 167. — FLOWER OF GARDEN NASTURTIUM.

Separate petal at *a*. The calyx is produced into a spur.



FIG. 168. — THE FIVE PETALS OF THE PANSY, detached to show the form.



FIG. 169. — AN IRREGULAR TWO-LIPPED COROLLA.

Various Forms of Corolla. — The corolla often assumes very definite or distinct forms, especially when gamopetalous. It may have a long tube with a wide-flaring limb, when it is said to be **funnelform**, as in morning-glory and pumpkin. If the tube is very narrow and the limb stands at right angles to it, [the corolla is **salverform**, as in phlox. If the tube is very short and the limb wide-spreading and nearly circular in outline, the corolla is **rotate** or **wheel-shaped**, as in potato.

A gamopetalous corolla or a gamosépalous calyx is often cleft in such way as to make two prominent parts. Such parts are said to be **lipped** or **labiate**.

Each of the lips or lobes may be notched or toothed. In 5-membered flowers, the lower lip is usually 3-lobed and the upper one 2-lobed. Labiate flowers are characteristic of the mint family (Fig. 170), and the family therefore is called the Labiatae.



(Literally, labiate means merely "lipped," without specifying the number of lips or lobes; but it is commonly used to designate 2-lipped flowers.)

Strongly 2-parted polypetalous flowers may be said to be labiate; but the term is oftenest used for gamopetalous corollas.

FIG. 170. — LABIATE FLOWER OF WILD BERGAMOT.

Labiate gamopetalous flowers that are closed in the throat (or entrance to the tube) are said to be **grinning** or **personate** (personate means *masked*, or *personlike*). Snapdragon is a typical example; but this type of corolla is also found in many related plants. Personate flowers usually have definite relations to insect pollination. Observe how an insect forces his head into the closed throat of the snapdragon.

The peculiar flowers of the pea tribes are explained in Figs. 171, 172.

Spathe Flowers. — In many plants, very simple (often naked) flowers are borne in dense, more or less fleshy spikes, and the spike is inclosed in or attended by a leaf, sometimes corolla-like, known as a **spathe**. The spike of flowers is technically known as a **spadix**. This type of flower is characteristic of the great arum family, which is chiefly tropical. The commonest wild representatives in the North are Jack-in-the-pulpit, or Indian turnip, and water

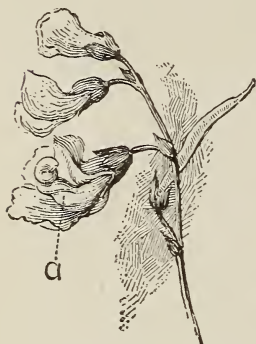


FIG. 171. — FLOWERS OF THE COMMON BEAN, with one flower opened (*a*) to show the structure.

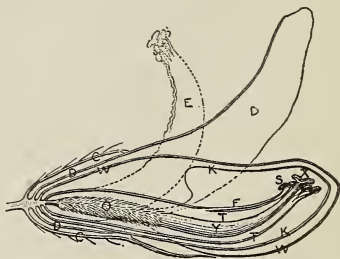


FIG. 172. — DIAGRAM OF ALFALFA FLOWER IN SECTION:

C, calyx; *D*, standard; *W*, wing; *K*, keel; *T*, stamen tube; *F*, filament of tenth stamen; *X*, stigma; *Y*, style; *O*, ovary; the dotted lines at *E* show position of stamen-tube, when pushed upward by insects. Enlarged.

arum. These flowers are not found in western Canada. The only flower of the type available for the student is the common calla, frequently grown as a house plant.

Compositous Flowers. — The head (anthodium) or so-called "flower" of sunflower (Fig. 173), thistle, aster, dandelion, daisy, sow thistle, goldenrod, is composed of several or many little flowers, or **florets**. These florets are inclosed in a more or less dense and usually green *involucre*. In the thistle (Fig. 174) this involucre is prickly. A longitudinal section discloses the florets, all attached at bottom

to a common torus, and densely packed in the involucre. The pink tips of these florets constitute the showy part of the head.

Each floret of the thistle (Fig. 174) is a complete flower. At *a* is the ovary. At *b* is a much-divided plumy calyx, known as the **pappus**. The corolla is long-tubed, rising above the pappus, and is enlarged and 5-lobed at the top, *c*. The

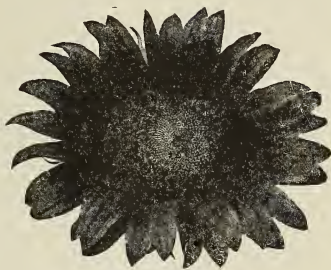


FIG. 173.—HEAD OF SUNFLOWER.

style projects at *e*. The five anthers are united about the style in a ring at *d*. Such anthers are said to be **syngene-**

sious. These are the various parts of the florets of the *Compositæ*. In some cases the pappus is in the form of barbs, bristles, or scales, and sometimes it is wanting. The pappus, as we shall see later, assists in distributing the seed. Often the florets are not all alike. The corolla of those in the outer circles may be developed into a *long, strap-like, or tubular part*, and the head then has the appearance of being one

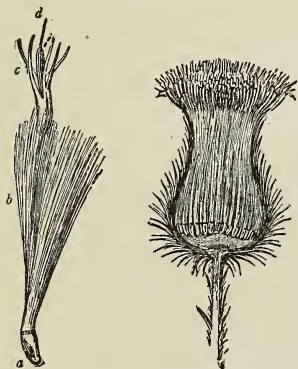


FIG. 174.—LONGITUDINAL SECTION OF THISTLE HEAD; also a FLORET OF THISTLE.

flower with a border of petals. Of such is the sunflower (Fig. 173), aster, cone flower, golden aster, and field daisy. These long corolla-limbs are called **rays**. In some cultivated

composites, all the florets may develop rays, as in the dahlia and chrysanthemum. In some species, as dandelion, all the florets naturally have rays. Syngenesious arrange-



FIG. 175.—PETALS ARISING FROM THE STAMINAL COLUMN OF HOLLYHOCK, and accessory petals in the corolla-whorl.

ment of anthers is the most characteristic single feature of the composites.

Double Flowers.—

Under the stimulus of cultivation and increased food supply, flowers tend to become double. True doubling arises in two ways, morphologically: (1) *stamens or pistils may produce petals* (Fig. 175); (2) *adventitious or accessory petals may arise in the circle of petals*.

Both of these categories may be present in the same flower.



FIG. 176.—NARCISSUS OR DAFFODIL. Single flower at the right.

In the full double hollyhock the petals derived from the staminal column are shorter and make a rosette in the centre of the flower. In Fig. 176 is shown the doubling of a daffodil by the modification of stamens. Other modifications of flowers are sometimes known as doubling. For example, double dahlias, chrysanthemums, and sunflowers are forms in which the disk flowers have developed rays. The snowball is another case. In the wild snowball the external flowers of the cluster are large and sterile. In the cultivated plant all the flowers have become large and sterile. Hydrangea is a similar case.

SUGGESTIONS. —

1. If the pupil has been skillfully conducted through this chapter *by means of careful study of specimens* rather than as a mere memorizing process, he will be in mood to challenge any flower that he sees and to make an effort to understand it. Flowers are endlessly modified in form; but they can be understood if the pupil looks first for the anthers and ovaries. How many anthers and ovaries always be distinguished?

2. It is excellent practice to find the flowers in plants that are commonly known by name, and to determine the main points in their structure. What are the flowers in Indian corn? pumpkin or squash? beet? cabbage? potato? pea? tomato? elm? poplar? rhubarb? willow? wheat? oats? Do all forest trees have flowers? Explain. Name all the monœcious plants you know. Dicœcious.

3. What plants do you know that bloom before the leaves appear? Do any bloom after the leaves fall?

4. Explain the flowers of marigold, hyacinth, lettuce, clover, garden calla, aster, caragana, onion, burdock, wild flag, Golden Glow rudbeckia, alfalfa.

5. Define a *flower*.

NOTE TO THE TEACHER. — It cannot be urged too often that *the specimens themselves* be studied. If this chapter becomes a mere recitation on names and definitions, the exercise will be worse than useless. Properly taught by means of the flowers themselves, the names become merely incidental and a part of the pupil's language, and the subject has living interest.

CHAPTER XIX

THE FLOWER—FERTILIZATION AND POLLINATION

Fertilization.—*Seeds result from the union of two elements or parts.* One of these elements is a cell-nucleus

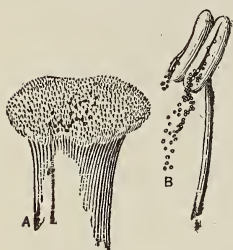


FIG. 177. — B, POLLEN escaping from anther; A, pollen germinating on a stigma. Enlarged.

of the pollen-grain. The other element is the cell-nucleus of an egg-cell, borne in the ovary. The pollen-grain falls on the stigma (Fig. 177). It absorbs the juices exuded by the stigma, and grows by sending out a tube (Fig. 178). This tube grows downward through the style, absorbing food as it goes, and finally reaches the egg-cell in the interior of an ovule in the ovary (Fig. 179), and fertilization,

or union of a nucleus of the pollen and the nucleus of the egg-cell in the ovule, takes place. *The ovule and embryo within then develops into a seed.* The growth of the pollen-tube is often spoken of as germination of the pollen, but it is not germination in the sense in which the word is used when speaking of seeds.

Better seeds—that is, those that produce stronger and more fruitful plants—often result when the *pollen comes from another flower*. Fertilization effected between different flowers is **cross-fertilization**; that resulting from the



FIG. 178. — A POLLEN-GRAIN AND THE GROWING TUBE.

application of pollen to pistils in the same flower is **close-fertilization** or **self-fertilization**. It will be seen that the cross-fertilization relationship may be of many degrees—between two flowers in the same cluster, between those in different clusters on the same branch, between those on different plants. Usually fertilization takes place only between plants of the same species or kind.

In many cases there is, in effect, *an apparent selection of pollen* when pollen from two or more sources is applied to the stigma. Sometimes the foreign pollen, if from the same kind of plant, grows, and fertilization results, while pollen from the same flower is less promptly effective. If, however, no foreign pollen is present, the pollen from the same flower may finally serve the same purpose.

In order that the pollen may grow, *the stigma must be ripe*. At this stage the stigma is usually moist and sometimes sticky. A ripe stigma is said to be **receptive**. The stigma may remain receptive for several hours or even days, depending on the kind of plant, the weather, and how soon pollen is received. Watch a certain flower every day to see the anther locules open and the stigma ripen. When fertilization takes place, the stigma dies. Observe, also, how soon the petals wither after the stigma has received pollen.

Pollination.—The transfer of the pollen from anther to stigma is known as **pollination**. The pollen may

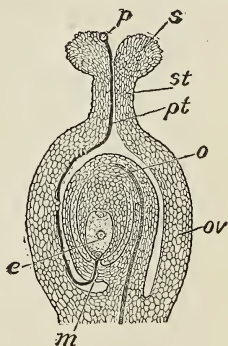


FIG. 179.— DIAGRAM TO REPRESENT FERTILIZATION.

s, stigma; st, style; ov, ovary; o, ovule; p, pollen-grain; pt, pollen-tube; e, egg-cell; m, micropyle.

fall of its own weight on the adjacent stigma, or it may be carried from flower to flower by wind, insects, or other agents. There may be **self-pollination** or **cross-pollination**, and of course it must always precede fertilization.



FIG. 180. —
ANTHER OF
AZALEA,
opening by
terminal
pores.

Usually the pollen is discharged by the bursting of the anthers. The commonest method of discharge is through a *slit* on either side of the anther (Fig. 177). Sometimes it discharges through a *pore* at the apex, as in azalea (Fig. 180), rhododendron, huckleberry, wintergreen. In some plants a part of the anther wall rises or falls as a *lid*, as in barberry (Fig. 181). This method is rare. The opening of an anther

(as also of a seed-pod) is known as **dehiscence** (*de*, from; *hisco*, to gape). When an anther or seed pod opens, it is said to *dehisce*.

Most flowers are so constructed as to increase the chances of cross-pollination. We have seen that the stigma may have the power of choosing foreign pollen. The commonest means of necessitating cross-pollination is the *different times of maturing of stamens and pistils in the same flower*. In most cases the stamens mature first: the flower is then **proterandrous**. When the pistils mature first, the flower is **proterogynous**. (*Aner*, *andr*, is a Greek root often used, in combinations, for stamens, and *gyne* for pistil.) The difference in time of ripening may be an hour or two, or it may be a day. The ripening of the stamens and pistils at different times is known as **dichogamy**, and flowers of such character are said to be dichogamous. There is little chance for dichogamous flowers to pollinate themselves. Many flowers are *imperfectly dichogamous* —



FIG. 181. —
BARBERRY
STAMEN,
with anther
opening by
lids.

some of the anthers mature simultaneously with the pistils, so that there is chance for self-pollination in case foreign pollen does not arrive. Even when the stigma receives pollen from its own flower, cross-fertilization may result. The hollyhock is proterandrous. Fig. 182 shows a flower recently



FIG. 182.—FLOWER OF HOLLYHOCK ; proterandrous.

expanded. The centre is occupied by the column of stamens. In Fig. 183, showing an older flower, the long styles are conspicuous.

Some flowers are so constructed as to prohibit self-pollination. Very irregular flowers are usually of this kind.



FIG. 183.—OLDER FLOWER OF HOLLYHOCK.

With some of them, the petals form a sac to inclose the anthers and the pollen cannot be shed on the stigma but is retained until a bee forces the sac open ; the pollen is rubbed on the hairs of the bee and transported.

Regular flowers usually depend mostly on dichogamy and the selective power of the pistil to insure crossing. *Flowers that are very*

irregular and provided with nectar and strong perfume are usually pollinated by insects. Gaudy colors probably attract insects in many cases, but perfume appears to be a greater attraction.



FIG. 184.—FLOWER OF LARKSPUR.

The insect *visits the flower for the nectar* (for the making of honey) *and may unknowingly carry the pollen.* Spurs and sacs in the flower are **nectaries** (Fig. 184), but in spurless flowers the nectar is usually secreted *in the bottom of the flower cup.* This compels the insect to pass by the anther and rub against the pollen before it reaches the nectar. Sometimes the anther is a

long lever poised on the middle point and the insect bumps against one end and lifts it, thus bringing the other end of the lever with the pollen sacs down on its back. Flowers that are pollinated by insects are said to be **entomophilous** ("insect loving"). Fig. 184 shows a larkspur. The envelopes are separated in Fig. 185. The long spur at once suggests insect pollination. The spur is a sepal. Two hollow petals project into this spur, apparently serving to guide the bee's tongue. The two smaller petals, in front, are peculiarly colored and perhaps serve the bee in locating the nectary. The stamens ensheath the pistils (Fig. 186). As the insect stands on the flower and thrusts its head into the centre,

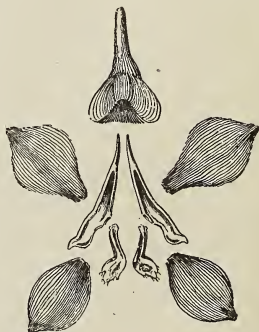


FIG. 185.—ENVELOPES OF A LARKSPUR. There are five wide sepals, the upper one being spurred. There are four small petals.

the envelopes are pushed downwards and outwards and the pistil and stamens come in contact with its abdomen. Since the flower is proterandrous, the pollen that the pistils receive from the bee's abdomen must come from another flower. Note a somewhat similar arrangement in the toadflax or butter-and-eggs.

In some cases (Fig. 187 *b*) the stamens are longer than the pistil in one flower and shorter in another. If the insect visits such flowers, it gets pollen on its head from the long-stamen flower, and deposits this pollen on the stigma in the long-pistil flower. Such flowers are **dimorphous** (of two forms). If pollen from its own flower and from another flower both fall on the stigma, the probabilities are that the stigma will choose the foreign pollen.



FIG. 186. — STAMENS OF LARKSPUR, surrounding the pistils.

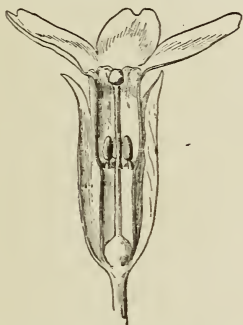


FIG. 187 *a*. — PRIMROSE WITH PISTIL LONGER THAN STAMENS.

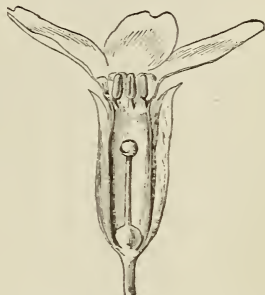


FIG. 187 *b*. — PRIMROSE WITH PISTIL SHORTER THAN STAMENS.

Many flowers are pollinated by the wind. They are said to be **anemophilous** ("wind loving"). Such flowers pro-

duce great quantities of pollen, for much of it is wasted. They usually have broad stigmas, which expose large surfaces to the wind. They are usually lacking in gaudy colors and in perfume. Grasses and pine trees are typical examples of anemophilous plants.

In many cases cross-pollination is insured because the *stamens and pistils are in different flowers* (diclinous).

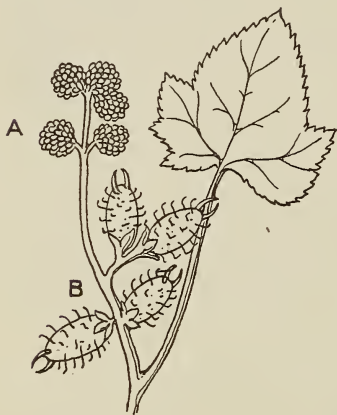


FIG. 188.—FLOWERS OF COCKLE BUR: pistillate flowers at A, and staminate flowers at B.

Monœcious and dioecious plants may be pollinated by wind or insects, or other agents (Fig. 188). They are usually wind-pollinated, although willows are often, if not mostly, insect-pollinated. The Indian corn is a monoecious plant. The staminate flowers are in a terminal panicle

(tassel). The pistillate flowers are in a dense spike (ear), inclosed in a sheath or husk. Each "silk" is a style. Each pistillate flower produces a kernel of corn. Sometimes a few pistillate flowers are borne in the tassel and a few staminate flowers on the tip of the ear. Is self-fertilization possible with the corn? Why does a "volunteer" stalk standing alone in a garden have only a few grains on the ear? What is the direction of the prevailing wind in summer? If only two or three rows of corn are

planted in a garden where prevailing winds occur, in which direction would they better run?

Although most flowers are of such character as to insure or increase the chances of cross-pollination, there are some *that absolutely forbid crossing*. These flowers are usually borne beneath or on the ground, and they lack showy colors and perfumes. They are known as **cleistogamous flowers** (meaning "hidden flowers"). The plant has normal showy flowers that may be insect-pollinated, and in addition is provided with these simplified flowers. Only a few plants bear cleistogamous flowers. Hog-peanut, and common blue violet, are about the only examples to be found in the Western Provinces of Canada. Fig. 189 shows a cleistogamous flower of the blue violet at *a*. Above

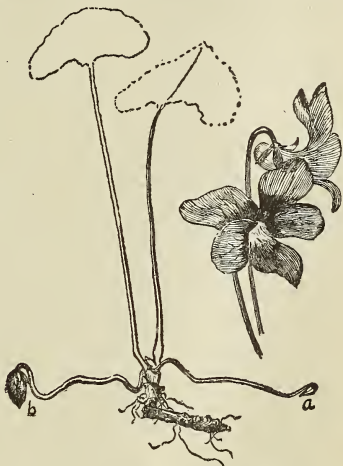


FIG. 189.—COMMON BLUE VIOLET. The familiar flowers are shown, natural size. The corolla is spurred. Late in the season, cleistogamous flowers are often borne on the surface of the ground. A small one is shown at *a*. A nearly mature pod is shown at *b*. Both *a* and *b* are one third natural size.

the true roots, slender stems bear these flowers, that are provided with a calyx, and a curving corolla which does not open. Inside are the stamens and pistils. Late in the season the cleistogamous flowers may be found just underneath the mold. They never rise above ground. The following summer one may find a seedling plant, in

some kinds of plants, with the remains of the old cleistogamous flower still adhering to the root. Cleistogamous

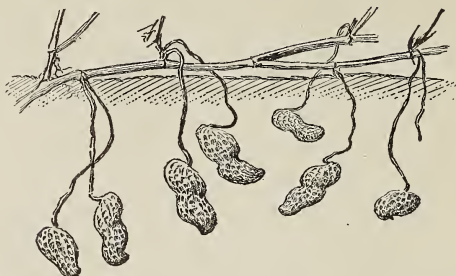


FIG. 190.—PODS OF PEANUTS RIPENING UNDERGROUND.

flowers usually appear after the showy flowers have passed. They seem to insure a crop of seed by a method that expends little of the plant's energy. The pupil will be interested to work out the fruiting of the peanut (Fig. 190). Unbaked fresh peanuts grow readily and can easily be raised in the North in a warm sandy garden or window box.



FIG. 191.—SEEDLING OF HOG PEANUT, with remains of the cleistogamous flower adhering.

SUGGESTIONS. —

1. *Not all the flowers produce seeds.* Note that fruit trees may bloom very full, but that only relatively little fruit may result.

2. *More pollen is produced than is needed to fertilize the flowers.* This increases the chances that sufficient stigmas will receive acceptable pollen to enable the plant to perpetuate its kind. At any time in summer, or even in fall, examine the fruit trees carefully to determine whether any dead flowers or flower stalks still remain about the fruit; or, examine any full-blooming plant to see whether any of the flowers fail.

3. Keep watch on any plant to see whether insects visit it. What kind? When? What for?

4. Determine whether the calyx serves any purpose in protecting the flower. Very carefully remove the calyx from a bud that is normally exposed to heat and sun and rain, and see whether the flower then fares as well as others.

5. Cover a single flower on its plant with a tiny paper or muslin bag so tightly that no insect can get in. If the flower sets fruit, what do you conclude?

6. Remove carefully the corolla from a flower nearly ready to open, preferably one that has no other flowers very close to it. Watch for insects.

7. Find the nectar in any flower that you study.

8. Remove the stigma. What happens?

9. Which of the following plants have perfect flowers: pea, bean, pumpkin, clover, potato, Indian corn, watermelon, sunflower, rose, begonia, geranium, cucumber, calla, willow, cottonwood? What have the others?

10. On wind-pollinated plants, are either anthers or stigmas more numerous? Are very small colored flowers usually borne singly or in clusters? Why do rains at blooming time often lessen the fruit crop?

11. *The crossing of plants to improve varieties or to obtain new varieties.*—It may be desired to perform the operation of pollination by hand. In order to insure the most definite results, every effort should be made rightly to apply the pollen which it is desired shall be used, and rigidly to exclude all other pollen. (a) The first requisite is to remove the anthers from the flower which it is proposed to cross, and they *must be removed before the pollen has been shed*. The flower-bud is therefore opened and the anthers taken out. Cut off the floral envelopes with small, sharp-pointed scissors, then cut out or pull out the anthers, leaving only the pistil untouched; or merely open the corolla at the end and pull out the anthers with a hook or tweezers; and this method is often the best one. It is best to delay the operation as long as possible and yet not allow the bud to open (and thereby expose the flower to foreign pollen) nor the anthers to discharge the pollen. (b) The flower *must next be covered with a paper bag to prevent the access of pollen* (Figs. 192, 193). If the stigma is not receptive at the time (as it usually is not), the desired pollen is not applied at once. The bag may be removed from time to time to allow of examination of the pistil, and when the stigma is mature, which is told by its glutinous or roughened appearance,

the time for pollination has come. If the bag is slightly moistened, it can be puckered more tightly about the stem of the plant.

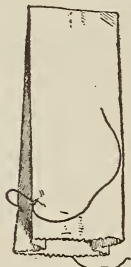


FIG. 192. — A PAPER BAG with string inserted.



FIG. 193. — THE BAG TIED OVER A FLOWER.

The time required for the stigma to mature varies from several hours to a few days. (c) When the stigma is ready, an unopened anther from the desired flower is crushed on the finger nail or a knife blade, and the pollen is rubbed on the stigma by means of a tiny brush, the point of a knife blade, or a sliver of wood. The flower is *again covered with the bag*, which is allowed to remain for several days until all danger of other pollination is past. Care must be taken completely to cover the stigmatic surface with pollen, if possible. The seeds produced by a crossed flower produce *hybrids*, or plants having parents belonging to different varieties or species. One of the means of securing new forms of plants is by making hybrids. Why?

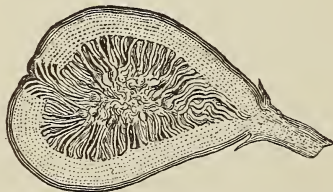


FIG. 194. — FIG. The fig is a hollow torus with flowers borne on the inside, and pollinated by insects that enter at the apex.

CHAPTER XX

FLOWER-CLUSTERS

Origin of the Flower-cluster. — We have seen that branches arise from the axils of leaves. Sometimes the leaves may be reduced to bracts and yet branches are borne in their axils. Some of the branches grow into long limbs ; others become short spurs ; *others bear flowers*. In fact, a flower is itself a specialized branch.

Flowers are usually borne near the top of the plant. Often they are produced in great numbers. It results, therefore, that flower branches usually stand close together, forming a **cluster**. The shape and arrangement of the flower-cluster *differ with the kind of plant*, since each plant has its own mode of branching.

Certain definite or well-marked types of flower-clusters have received names. Some of these names we shall discuss, but the flower-clusters that perfectly match the definitions are the exception rather than the rule. The determining of the



FIG. 195. — TERMINAL SOLITARY FLOWER OF THE TULIP.

kinds of flower-clusters is one of the most perplexing subjects in descriptive botany. We may classify the subject around three ideas: **solitary flowers**, **centrifugal** or **determinate clusters**, **centripetal** or **indeterminate clusters**.

Solitary Flowers.—In many cases flowers are borne singly; they are separated from other flowers by leaves. They are then said to be **solitary**. The solitary flower may

be either at the end of the main shoot or axis (Fig. 195), when it is said to be **terminal**; or from the side of the shoot (Fig. 196), when it is said to be **lateral** or **axillary**.



FIG. 196. — LATERAL SOLITARY FLOWER OF THE PETUNIA.

Centripetal Clusters.—If the flower-bearing axils were rather close together, an open or leafy flower-cluster might result. If the plant continues to grow from the tip, the older flowers are left farther and farther behind. If the cluster were so short as to be flat or convex on top, the outermost flowers would be the

older. A flower-cluster in which the lower or outer flowers open first is said to be a **centripetal cluster**. It is sometimes said to be an **indeterminate cluster**, since it is the result of a type of growth which may go on more or less continuously from the apex.

The simplest form of a definite, centripetal cluster is a **raceme** which is an open, elongated cluster in which the *flowers are borne singly on very short branches* and open from below (that is, from the older part of the shoot)

upwards (Fig. 197). The raceme may be *terminal* to the main branch; or it may be *lateral* to it, as in Fig. 198.

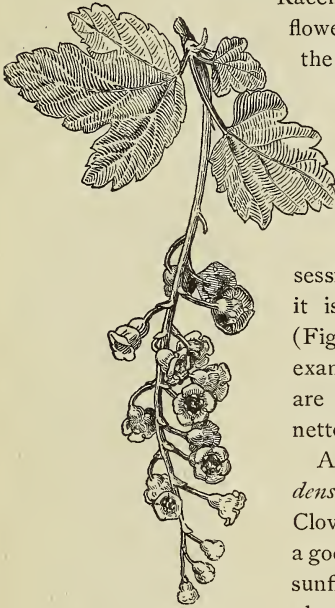


FIG. 197. — RACEME OF CURRANT.
Terminal or lateral?

Racemes often bear the flowers on one side of the stem, thus forming a single row.

When a centripetal flower-cluster is long and dense and the flowers are sessile or nearly so, it is called a **spike** (Fig. 199). Common examples of spikes are plantain, mignonne.

A very *short and dense spike* is a **head**. Clover (Fig. 200) is a good example. The sunflower and related

plants bear many small flowers in a

very dense and often flat head. Note that in the sunflower (Fig. 173) the outside or exterior flowers



FIG. 198. — LATERAL RACEMES (in fruit).



FIG. 199. —
SPIKE OF
PLANTAIN.

open first. Another special form of spike is the **catkin**, which usually has scaly bracts, the whole cluster being deciduous after flowering or fruiting, and the flowers (in typical cases) having only stamens or pistils. Examples are the "pussies" of willows and flower-clusters of oak and poplars.



FIG. 200.—HEAD OF CLOVER BLOSSOMS.



FIG. 201.—CORYMB OF CANDY-TUFT.

When a loose, elongated, centripetal flower-cluster has some primary branches simple, and others irregularly branched, it is called a **panicle**. It is a branching raceme. Because of the earlier growth of the lower branches, the panicle is usually broadest at the base or conical in outline. True panicles are not very common.

When an indeterminate flower-cluster is short, so that

the *top is convex or flat*, it is a **corymb** (Fig. 201). The outermost flowers open first. Centripetal flower-clusters are sometimes said to be corymbose in mode.

When the branches of an indeterminate cluster *arise from a common point*, like the frame of an umbrella, the cluster is an **umbel** (Fig. 202). Typical umbels occur in car-



FIG. 202. — COMPOUND UMBEL OF WILD CARROT.

rot, parsnip, caraway and other plants of the parsley family : the family is known as the Umbelliferae, or umbel-bearing family. In the carrot and many other Umbelliferae, there are small or secondary umbels, called **umbellets**, at the end of each of the main branches, making the umbel compound. A sessile flower or aborted umbel is often found in the centre of the compound umbel.



FIG. 203. — DETERMINATE OR CYMOSE ARRANGEMENT. — Wild geranium.

Centrifugal or Determinate Clusters. — When the terminal or central flower opens first, the cluster is said to be **centrifugal**. The growth of the shoot or cluster is **determinate**, since the length is definitely determined or stopped by the terminal flower. Fig. 203 shows a determinate or centrifugal mode of flower bearing.

Dense centrifugal clusters are usually flattish on top because of the cessation of growth in the main or central axis.

These compact flower-clusters are known as **cymes**. Centrifugal clusters are sometimes said to be cymose in mode. Elders (Fig. 204) and some cherries bear flowers in cymes.



FIG. 204. — CYME OF RED ELDER IN FRUIT.

Some cyme-forms are like umbels in general appearance. A head-like cymose cluster is a **glomerule**; it blooms from the top downwards rather than from the base upwards.

Mixed Clusters. — Often the cluster is mixed, being determinate in one part and indeterminate in another part of the same cluster.

The main cluster may be indeterminate, but the branches determinate. The cluster has the appearance of a panicle, and is usually so called, but it is really a **thyrs**e. Lilac is a familiar example of a thyrs. In some cases the main cluster is determinate and the branches are indeterminate, or apparently so.

Inflorescence. — The *mode* or *method* of flower arrangement is known as the **inflorescence**. That is, the inflorescence is cymose, corymbose, paniculate, spicate, solitary, determinate, indeterminate. By custom, however, the word "inflorescence" has come to be used for the *flower-cluster itself* in works on descriptive botany. Thus a cyme or a panicle may be called an inflorescence. It will be seen that even solitary flowers follow either indeterminate or determinate methods of branching.

The flower-stem. — The stem of a solitary flower is known as a **peduncle**; also the general stem of a *flower-cluster*. The stem of the individual flower in a cluster is a **pedicel**. In the so-called stemless plants the peduncle may arise directly from the ground, or crown of the plant,

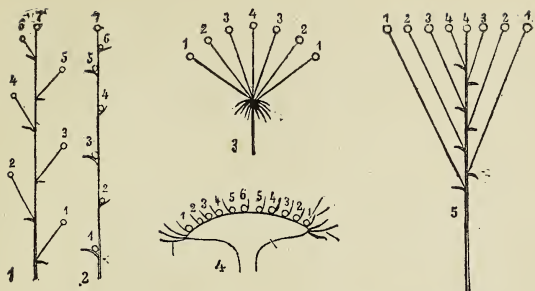


FIG. 205. — FORMS OF CENTRIPETAL FLOWER-CLUSTERS.

1, raceme; 2, spike; 3, umbel; 4, head or anthodium; 5, corymb.



FIG. 206. — CENTRIPETAL INFLORESCENCE, *continued*.

6, spadix; 7, compound umbel; 8, catkin.

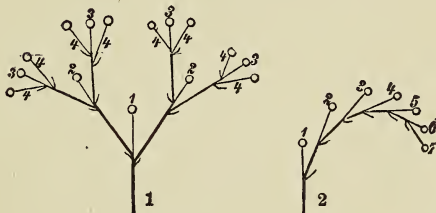


FIG. 207. — CENTRIFUGAL INFLORESCENCE.

1, cyme; 2, scirpioid raceme (or half cyme).

as in dandelion, hyacinth, garden daisy; this kind of peduncle is called a **scape**. A scape may bear one or many flowers. It has no foliage leaves, but it may have bracts.

SUGGESTIONS. —

1. Name six columns in your notebook as follows: spike, raceme, corymb, umbel, cyme, solitary. Write each of the following in its appropriate column: larkspur, grape, rose, wild onion, phlox, pin cherry, choke cherry, saskatoon, high bush cranberry, honeysuckle, aster, lily, carrion flower, penny-cress, everlasting pea, oats, willow, birch, poplar, false Solomon's seal, mustard, golden-rod, hollyhock, snapdragon, peppergrass, shepherd's purse, wheat, hawthorn, geranium, carrot, elder, dogwood; substitute others for plants that do not grow in your region.

2. In the study of flower-clusters, it is well to choose first those that are fairly typical of the various classes discussed in the preceding paragraphs. As soon as the main types are well fixed in the mind, random clusters should be examined, for the pupil must never receive the impression that all flower-clusters follow the definitions in books. Clusters of some of the commonest plants are very puzzling, but the pupil should at least be able to discover whether the inflorescence is determinate or indeterminate. Figures 205 to 207 illustrate the theoretical modes of inflorescence. The numerals indicate the order of opening.

CHAPTER XXI

FRUITS

THE ripened ovary, with its attachments, is known as the **fruit**. *It contains the seeds.* If the pistil is simple, or of one carpel, the fruit also will have one compartment. If the pistil is compound, or of more than one carpel, the fruit usually has an equal number of compartments. The compartments in pistil and fruit are known as **locules** (from Latin *locus*, meaning "a place").

The simplest kind of fruit is a *ripened 1-loculed ovary*. The first stage in complexity is a ripened *2- or many-loculed ovary*. Very complex forms may arise by the *attachment of other parts to the ovary*. Sometimes the style persists and becomes a beak, as in wild mustard (Fig. 208), or a tail (early anemone); or the calyx may be attached to the ovary; or the ovary may be imbedded in the receptacle, and ovary and receptacle together constitute the fruit: or an involucre may become a part of the fruit, as possibly cup of the acorn (Fig. 210). The hazelnuts bear a prickly involucre, but the nuts, or true fruits, are not grown fast to it, and the involucre can

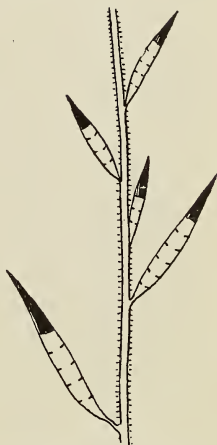


FIG. 208.—FRUIT OF WILD MUSTARD.



FIG. 209. — SINGLE SAMARA OF THE GREEN ASH.

scarcely be called a part of the fruit. A ripened ovary is a **pericarp**. A pericarp to which other parts adhere has been called an **accessory** or **reinforced** fruit.



FIG. 210. — BUR-OAK ACORN. The fruit is the "seed" part; the involucre is the "cup."

Some fruits are **dehiscent**, or split

open at maturity and liberate the seeds; others are **indehiscent**, or do not open. A dehiscent pericarp is called a **pod**. The parts into which such a pod breaks or splits are known as **valves**. In indehiscent fruits the seed is liberated by the decay of the envelope, or by the rupturing of the envelope by the germinating seed. In dehiscent, winged pericarps are known as **samaras** or **key fruits**. Maple (Fig. 211), elm (Fig. 212), and ash (Fig. 209) are examples.



FIG. 211. — DOUBLE SAMARA OF THE BOX ELDER OR MANITOBA MAPLE.

Pericarps. — The simplest pericarp is a dry, one-seeded, indehiscent body. It is known

as an **akene**.

A head of akenes is shown in

Fig. 213, and the structure is

explained in Fig. 214. Akenes may be seen in three-flowered avens, buttercup, hepatica, anemone.



FIG. 213. — AKENES OF BUTTERCUP.



FIG. 212. — KEY OF COMMON AMERICAN ELM.

A 1-loculed pericarp which dehisces along the front edge (that is, the inner edge, next the centre of the flower) is a **follicle**. The fruit of

the larkspur (Fig. 215) is a follicle.

There are usually five of these fruits (sometimes three or four) in each larkspur flower, each pistil ripening into a follicle.

If these pistils were united, a single compound pistil

would be formed. Columbine, peony, marsh marigold, milkweed, also have follicles.



FIG. 215. — FOLLICLE OF LARKSPUR.



FIG. 214. — AKENES OF BUTTERCUP, one in longitudinal section.

A 1-loculed pericarp that dehiscence on both edges is a **legume**. Peas and beans are typical examples (Fig. 216); in fact, this character gives name to the pea family, — Leguminosæ. Often the valves of the legume twist forcibly and expel the seeds, throwing them some distance. The word "pod" is sometimes restricted to legumes, but it is better to use it generically for all dehiscent pericarps.

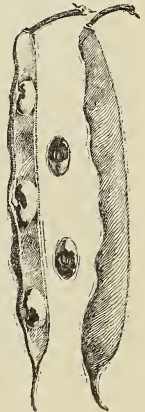


FIG. 216. — A BEAN POD.



FIG. 217. — CAPSULE OF CASTOR - OIL BEAN AFTER DEHISCENCE.

one locule, but they may have been compound when young (in the ovary stage) and the partitions may have vanished. Or 1-celled fruit, as a legume, may be made to resemble a capsule by the intrusion of a false partition in the cell. Again a



FIG. 218. — CAPSULE OF MORNING GLORY.

capsule may become 1-celled by the abortion of some of the cells.

There are several ways in which capsules dehisce or open. When they break



FIG. 219. — FRUIT OF THE GROUND PLUM, *ASTRAGALUS*, showing the legume divided into two cells by the intrusion of a false partition.

along the partitions (or septa), the mode is known as **septicidal dehiscence**

(Fig. 220). In septicidal dehiscence the fruit separates into parts represent-

ing the original carpels. These carpels may still be entire, and they then dehisce individually, usually along the inner edge as if they were follicles.

When the compartments *split in the middle, between the partitions*, the mode is **loculicidal dehiscence**

(Fig. 221). In some cases the dehiscence is *at the top*, when it is said to be **apical** (although several modes of dehiscence are here included). When the *whole*



FIG. 220. — A SEPTICIDAL CAPSULE.



FIG. 221. — A LOCULICIDAL CAPSULE.

top comes off, as in purslane and garden portulaca (Fig. 222), the pod is known as a **pyxis**. In some cases apical dehiscence is by means of a hole or clefts.



FIG. 222. — PYXIS OF PORTULACA OR ROSE-MOSS.

The peculiar capsule of the mustard family, or *Cruciferae*, is known as a **siliqua** when it is distinctly longer than broad (Fig. 224), and a **silicle** when its breadth

nearly equals or exceeds its length (Fig. 224). A cruciferous capsule is 2-carpeled, with a thin partition, each locule

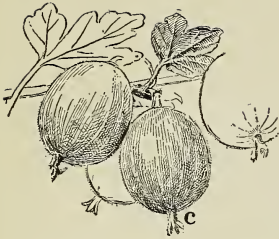


FIG. 223. — BERRIES OF GOOSE-BERRY. Remains of calyx at *c*.

seeds is a **berry** (Figs. 223, 225). To the horticulturist a berry is a small, soft, edible fruit, without particular reference to its structure. The botanical and horticultural conceptions of a berry are, therefore, unlike. In the botanical sense, gooseberries, currants, grapes, tomatoes, potato-balls, and even lemons and oranges (Fig. 225) are berries; strawberries, raspberries, blackberries are not.

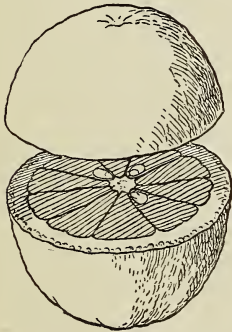


FIG. 225. — ORANGE; example of a berry.

containing seeds in two rows. The two valves detach from below upwards. Cabbage, turnip, mustard, penny-cress, radish, rape, shepherd's purse, sweet alyssum, wall-flower, are examples.

The pericarp may be *fleshy and indehiscent*. A pulpy pericarp with several or many



FIG. 224. — SILICLE OF SHEPHERD'S PURSE.

A fleshy pericarp containing one relatively large seed or stone is a **drupe**. Examples are plum (Fig. 226), peach, cherry, apricot, olive. The walls of the pit in the plum, peach, and cherry are formed from the inner coats of the ovary, and the flesh from the outer coats. Drupes are also known as *stone-fruits*.

Fruits that are formed by the

subsequent union of separate pistils are **aggregate fruits**. The carpels in aggregate fruits are usually more or less fleshy. In the raspberry and blackberry flower, the pistils are essentially distinct, but as the pistils ripen they cohere and form one body (Figs. 227, 228). Each of the carpels or pistils in the raspberry and blackberry is a little drupe, or **drupelet**. In the raspberry the entire fruit separates from the torus, leaving the torus on the plant. In the blackberry and dewberry the fruit adheres to the torus, and the two are removed together when the fruit is picked.



FIG. 226.—PLUM; example of a drupe.

Accessory Fruits.

—When the pericarp and some other part grow together, the fruit is said to be **accessory** or **reinforced**. An example is the strawberry (Fig. 229). The edible part is a greatly *enlarged torus*, and the pericarps are akenes embedded in it. These akenes are commonly called seeds.

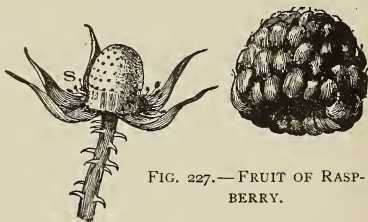


FIG. 227.—FRUIT OF RASPBERRY.



FIG. 228.—AGGREGATE FRUIT OF MULBERRY; and a separate fruit.

Various kinds of reinforced fruits have received special names. One of these is the **hip**, characteristic of roses. In this case, the torus is deep and hollow, like an urn, and the separate akenes are borne inside it. The mouth of the receptacle may close, and the walls sometimes become

fleshy; the fruit may then be mistaken for a berry. The fruit of the pear, apple, and quince is known as a **pome**. In this case the five united carpels are completely buried in the hollow torus, and the torus makes most of the edible part of the ripe fruit, while the pistils are represented by the core (Fig. 230). Observe the sepals on the top of the torus (apex of the fruit) in Fig. 230. Note the outlines of the embedded pericarp in Fig. 231.

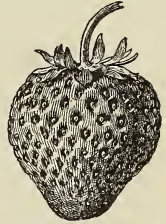


FIG. 229. — STRAWBERRY; fleshy torus in which akenes are embedded.

Gymnospermous Fruits. — In pine, spruces, and their kin, there is no fruit in the sense in which the word is used in the preceding pages, because *there is no ovary*. The ovules are naked or uncovered, in the axils of the scales of the young cone, and they have neither style nor stigma. The pollen falls

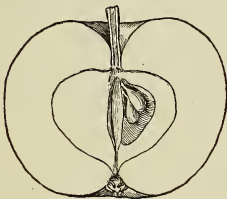


FIG. 230. — SECTION OF AN APPLE.



FIG. 231. — CROSS-SECTION OF AN APPLE.

directly on the mouth of the ovule. The ovule ripens into a seed, which is usually winged. Because the ovule is not borne in a sac or ovary, these plants are called **gymnosperms** (Greek for "naked seeds"). All the true cone-bearing plants are of this class; also certain other plants, as red cedar, juniper, yew. The plants are monœcious or some-

times diœcious. The staminate flowers are mere naked stamens borne beneath scales, in small yellow catkins which soon fall. The pistillate flowers are naked ovules beneath scales on cones that persist (Fig. 29). Gymnospermous seeds may have several cotyledons.

SUGGESTIONS. —

1. Study the following fruits, or any five fruits chosen by the teacher, and answer the questions for each: Apple, peach, bean, tomato, pumpkin. What is its form? Locate the scar left by the stem. By what kind of a stem was it attached? Is there any remains of the blossom at the blossom end? Describe texture and color of surface. Divide the fruit into the seed vessel and the surrounding part. Has the fruit any pulp or flesh? Is it within or without the seed vessel? Is the seed vessel simple or subdivided? What is the number of seeds? Are the seeds free, attached to the wall of the vessel, or to a support in the centre? Are they arranged in any order? What kind of wall has the seed vessel? What is the difference between a peach stone and a peach seed?

2. The nut fruits are always available for study. Note the points suggested above. Determine what the meat or edible part represents, whether cotyledons or not. Figure 232 is suggestive.

3. Mention all the fleshy fruits you know, tell where they come from, and refer them to their proper groups.

4. What kinds of fruits can you buy in the market, and to what groups or classes do they belong? Of which ones are the seeds only, and not the pericarps, eaten?

5. An ear of corn is always available for study. What is it — a fruit or a collection of fruits? How are the grains arranged on the cob? How many rows do you count on each of several ears? Are all the rows on an ear equally close together? Do you find an ear with an odd number of rows? How do the parts of the husk overlap? Does the husk serve as protection from rain? Can birds pick out the grains? How do insect enemies enter the ear? How and when do weevils lay eggs on corn?

6. *Study a grain of corn.* Is it a seed? Describe the shape of a grain. Color. Size. Does its surface show any projections or depressions? Is the seed-coat thin or thick? Transparent or opaque? Locate the hilum. Where is the silk scar? What is the silk? Sketch the grain from the two points of view that show

it best. Where is the embryo? Does the grain have endosperm? What is dent corn? Flint corn? How many kinds of corn do you know? For what are they used?

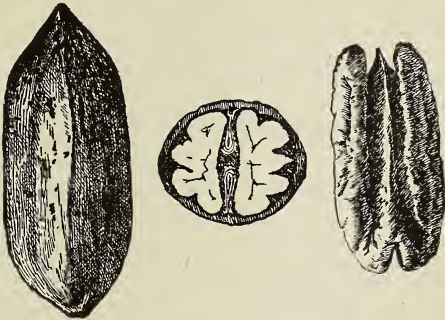


FIG. 232.—PECAN FRUIT.

NOTE TO TEACHER.—There are few more interesting subjects to beginning pupils than fruits,—the pods of many kinds, forms, and colors, the berries, and nuts. This interest may well be utilized to make the teaching alive. All common edible fruits of orchard and vegetable garden should be brought into this discussion. Of dry fruits, as pods, burs, nuts, collections may be made for the school museum. Fully mature fruits are best for study, and should be collected at the proper season and kept on hand. *Always note exterior of fruit and its parts: interior of fruit with arrangement and attachment of contents.*

CHAPTER XXII

DISPERSAL OF SEEDS

It is to the plant's advantage to have its seeds distributed as widely as possible. *It has a better chance of surviving in the struggle for existence.* It gets away from competition. Many seeds and fruits are of such character as to increase their chances of wide dispersal. The commonest means of dissemination may be classed under four heads: *explosive fruits ; transportation by wind ; transportation by birds ; burs.*



FIG. 233.—EXPLOSION OF
THE BALSAM POD.



FIG. 234.—EXPLOSIVE
FRUITS OF OXALIS.

An exploding pod is shown at *c*. The dehiscence is shown at *b*. The structure of the pod is seen at *a*.

Explosive Fruits. — *Some pods open with explosive force and discharge the seeds.* Even bean and everlasting peas do this. More marked examples are some members of the pea family, as the caragana, the garden balsam (Fig. 233), wild impatiens (touch-me-not), violet, crane's-bill or wild geranium, morning-glory, and the oxalis (Fig. 234). The

oxalis is common in several species in the wild and in cultivation. One of them is known as wood sorrel. Figure 234 shows the common yellow oxalis. The pod opens loculicidally. The elastic tissue suddenly contracts when dehiscence takes place, and the seeds are thrown violently. The squirting cucumber is easily grown in a garden (procure seeds from a seedsman), and the fruits discharge the seeds with great force, throwing them many feet.

Wind Travellers. — Wind-transported seeds are of two general kinds: those that are *provided with wings*, as the flat seeds of most of the cone-bearing trees and the samaras of ash, elm, and several kinds of maple; and those which have *feathery buoys* or *parachutes* to enable them to float in the air, as dandelion (Fig. 235). Of the latter kind are the fruits of many composites, in which the pappus is copious and soft. Dandelion and thistle are examples. The silk of the milkweed and of the great willow herb have a similar office, and also the wool of the cat-tail. Recall the cottony seeds of the willow and poplar.

Dispersal by Birds. — *Seeds of berries and of other small fleshy fruits are carried far and wide by birds.* The pulp is digested, but the seeds are not injured. Note how the cherries, raspberries, blackberries, June-berries, and others spring up in fence rows, where the birds rest. Some berries and drupes persist far into winter, when they supply food to cedar birds, robins, and the winter birds. Juniper is distributed by birds. Many of these pulpy fruits are agreeable as human food, and some of them

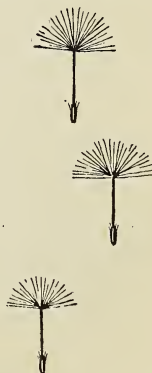


FIG. 235.—TUFTED SEED OF DANDELION.

have been greatly enlarged or "improved" by the arts of the cultivator. The seeds are usually indigestible.

Burs. — Many seeds and fruits bear spines, hooks, and hairs, which *adhere to the coats of animals and to clothing*. The burdock has an involucre with hooked scales, containing the fruits inside. The cocklebur is also an involucre. Both are compositous plants, allied to thistles, but the whole head, rather than the separate fruits, is transported. In some compositous fruits the pappus takes the form of hooks and spines, as in the "bur marigolds" or "pitch-forks." Fruits of various kinds are known as "stick tights," as of the agrimony and blue bur. Those who walk in the woods in late summer and fall are aware that plants have means of disseminating themselves. If it is impossible to identify the burs which one finds on clothing, the seeds may be planted and specimens of the plant may then be grown. —

SUGGESTIONS. —

1. What advantage is it to the plant to have its seeds widely dispersed? What are the leading ways in which fruits and seeds are dispersed?

2. Put some pods of sweet peas, everlasting peas, or caragana in a shallow vessel and set in a dry place. Note the explosive force of the bursting pods. Name some explosive fruits.

3. Describe wind travellers. What seeds are carried by birds? Describe some bur with which you are familiar. Are adhesive fruits usually dehiscent or indehiscent? Do samaras grow on low or tall plants, as a rule? Are the cotton fibres on the seed or on the fruit? Name the ways in which the common weeds of your region are disseminated.

4. This lesson will suggest other ways in which seeds are transported. Nuts are buried by squirrels for food; but if they are not eaten, they may grow. The seeds of many plants are blown on the snow. The old stalks of weeds, standing through the winter, may serve to disseminate the plant. Seeds are carried by water

down the streams and along shores. About woollen mills strange plants often spring up from seed brought in the fleeces. Sometimes the entire plant is rolled for miles before the winds. Such plants are "tumbleweeds." Examples are Russian thistle and tumbling mustard.

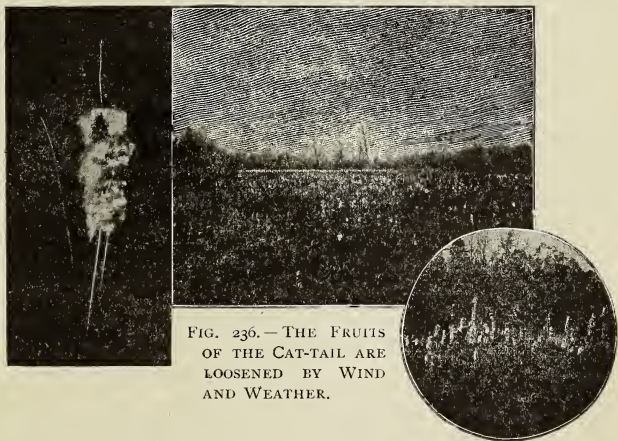


FIG. 236.—THE FRUITS
OF THE CAT-TAIL ARE
LOOSEMED BY WIND
AND WEATHER.

CHAPTER XXIII

WEEDS

A WEED is a plant which, by reason of its mode of growth; its superior vitality, or its means of propagation and distribution, is able to crowd out more useful plants in the struggle for existence. Any plant growing where it is not wanted, and hindering the growth of what is wanted, may under such circumstances be termed a weed. The name is more properly applied, however, to plants of little or no economic value themselves, and which are either strong competitors for food, light, and air, or are of unsightly appearance.

It is a somewhat remarkable fact that the native plants of our Canadian prairies have furnished very few, if any, really troublesome weeds. On the other hand, a considerable number of exceedingly troublesome European species have been introduced with field or garden seeds. It may be that these, by reason of their long association with cultivated crops, have learned to adapt themselves to the struggle, and live in spite of the discouragement of hoe and harrow, while our native plants, like our native birds, are still somewhat shy of the ways of man.

The injuries done by weeds are various and may be briefly summarized as follows :—

1. They crowd out useful plants.
2. They fill waste places and are of unsightly appearance.
3. They may be injurious to stock. Some are poisonous ; others, like stinkweed, taint milk ; while others again, by

reason of their awned seeds, cause sores in the mouths of cattle and horses.

4. They may attract injurious insects or cause disease. Cutworms and various kinds of fungous growths are known to be more troublesome on weedy than on well-tilled land.

The economic loss due to weeds is enormous. If the farmer could estimate his loss in time and labor, in yield, in machinery, and in expense for extra threshing and freight, it would be obvious that weeds constitute one of his serious problems.

In order to face this problem intelligently it is necessary to be able to recognize all injurious weeds and to understand thoroughly their life-history and mode of growth. The power of ready recognition makes possible the eradication of new weeds before they have become too plentiful, and a knowledge of the life-history of the plants insures the use of rational means for their control.

In order to understand the life-history of weeds it is convenient to divide them into three classes, viz. : —

1. *Annuals*, — those weeds that grow, mature their seeds and die in one season. These plants usually produce large quantities of seed, and the most successful method of treating them is by cutting, or by cultivation to prevent their going to seed. If the ground is already stocked with seeds of annuals, they may be grown out, *i.e.* the seeds allowed to germinate and then the young plants destroyed. It is more than probable that the stories told of some of these seeds germinating after being in the ground for fifty or seventy-five years are much overdrawn. Experiments have shown that some seeds will live in the ground for fifteen years; while the seed of the wild mustard, which has the greatest reputation in this respect, has been shown to live about twelve years. Seeds of many annual weeds,

however, will live for ten years in the ground and still germinate, although their vitality is greatly reduced.

2. *Biennials*,—those weeds which grow through two years. Usually they form a rosette of leaves and a strong root the first year, and in the second year send up a stem and produce flowers and seeds. They may be treated in the same way as annuals, and are easier to control.

3. *Perennials*,—weeds which grow on from year to year, the root or rootstock remaining in the ground. These are usually divided into (1) shallow-rooting perennials and (2) deep-rooting perennials. They include many of our most troublesome weeds, and are only successfully dealt with by preventing them from sending up leaves for a whole season. As the leaf is the digestive organ of the plant and can do its work only in the sunshine, no plant can live if cut off from the sun for a whole growing season.

Nearly all our most troublesome weeds belong to a few well-known plant families. A knowledge of the characteristics of these families will greatly assist not only in identifying plants which are known to be weeds, but also in detecting dangerous plants among new arrivals.

The Grass Family (*Gramineæ*).—This family has produced the following weeds which are troublesome in the west:—

Quack-grass or Couch-grass.—This grass is an introduction from Europe. It produces great mats of rootstocks just below the surface of the soil and thus crowds out other plants. It may be recognized by its persistence, its dark green leaves, and its matted shiny rootstocks tinged with greenish yellow.

Blue Joint or Western Quack-grass.—This is a native grass somewhat similar to the preceding, but may be distinguished by its gray green leaves and white rootstocks.

It is a common prairie grass in low places and will not give trouble in well-cultivated soil.

Skunk-tail Grass or Wild Barley. — This grass is frequently, but incorrectly, called foxtail. It injures hay because the awns irritate the mouths of horses and cattle.

Sweet Grass. — This is an early-flowering fragrant grass, troublesome in moist ground.

These grasses are all perennial, the first three being shallow rooted and the last deep rooted.

Wild Oats. — A very troublesome annual much resembling cultivated oats, and because of its similar habits very injurious to grain crops.

Darnel. — An annual somewhat resembling couch-grass, but with seeds about the size of wheat, and in appearance resembling small barley. The seeds are bitter to the taste and reputed poisonous. They are difficult to remove from wheat and lessen its market value. It has been introduced and is becoming common in the Red River Valley.

The Goosefoot Family (*Chenopodiaceæ*). — This family has produced a large number of weeds, the most troublesome being the following: —

Lamb's Quarters or Pigweed. — Too well known to require comment.

Russian Pigweed. — When young, resembling the preceding, but paler; when older, forming a rank, bushy weed, which takes possession of all waste places. Introduced from Russia, it was first found in Canada at Headingly in 1886.

Russian Thistle. — A branching, spiny annual which breaks off at the root and forms a tumble-weed. It is becoming a serious pest in Southern Manitoba.

Other members of this family like the oak-leaved goosefoot, the maple-leaved goosefoot, and the atriplex are un-



FIG. 237. — COMMON
WHITE PIGWEED.
Chenopodium album.

sightly but less troublesome. They are all annuals, and this fact determines the method of treatment.

The Amaranth Family (*Amaranthaceæ*). — This family closely resembles the preceding, and to it belongs the red-root pigweed. Its habits are similar to those of the other pigweeds and it requires similar treatment.

The Mustard Family (*Cruciferae*). — This family produces a great number of annual weeds. They are all readily recognized by their cross-shaped corolla and six stamens, two shorter than the other four. The numerous weeds of this family need only be named.

The following are all troublesome: stinkweed, wild mustard or charlock, shepherd's purse, tumbling mustard, gray tansy mustard, green tansy mustard, ball mustard, hare's ear mustard, wormseed mustard, peppergrass, false flax, and withlow grass. They are all annuals and spread by means of the large number of seeds produced.

The Sunflower Family (*Compositæ*). — This family has produced a large number of weeds, including annuals, biennials, and perennials. Many of the perennials are deep-rooted, making them difficult to eradicate. The habit of producing seeds provided with tufts, by means of which they are carried by the wind, enables many members of this family to spread widely



FIG. 238. — CANADA
THISTLE.

and makes them very difficult to control. The most troublesome members of this very large family are:—

1. *Perennials*. — Canada thistle, perennial sow thistle, perennial ragweed, dandelion, and wild sunflowers.

2. *Biennials*. — Biennial wormwood and burdock.

3. *Annuals*. — Great ragweed, false ragweed or marsh elder, blue lettuce, curly lettuce, and common fleabane.

The prairies and waste places are covered with other plants of this family, as the asters, bur marigolds, golden asters, cone-flowers, annual sow thistles, swamp thistles, prairie thistles, and golden-rods, any of which may be troublesome at times. These are not likely to be serious pests, but we have reason to fear the introduction of such weeds as the ox-eye daisy, fall dandelion, common ragwort, and orange hawk-weed, which so far have not made their appearance to any extent in the west.

The Buckwheat Family (*Polygonaceæ*). — This family has given us the knot-weed or goose-grass, the wild buckwheat or black bindweed, the docks, the smartweed, and the sheep sorrel. The first is a common dooryard weed wherever mankind dwells. The docks are not serious pests, and smartweed and sheep sorrel are as yet but locally introduced. A related species, *Polygonum amphibium*, is sometimes troublesome in



FIG. 239. — REDROOT
PIGWEEED. *Amaranthus*.



FIG. 240. — CHARLOCK.
A weed of grain fields
and open places.



FIG. 241. — GREAT RAGWEED.

newly cultivated, poorly drained land, but will not stand cultivation.

The Pink Family (*Caryophyllaceæ*). — To this family belong the cockles and chickweeds. Purple cockle, white cockle, cow cockle, night-flowering catchfly, bladder campion, and common chickweed are its worst members. Of these, all except the last mentioned are grain-crop weeds, and, so far, have not given serious trouble in western wheat fields. The common chickweed is a small, white-flowered annual which causes considerable trouble by crowding out the grass on old lawns. Wherever a lawn is somewhat shaded or the sod not close, this weed is likely to be injurious. It is introduced, and is mostly found about towns and in the older-settled districts.

The Borage Family (*Boraginaceæ*). — The blue bur is the only weed this family has given us thus far. It is a biennial and easily controlled, but



FIG. 242. — BUR MARIGOLD.

its small burs cause great inconvenience by becoming attached to clothing. It is a serious pest where sheep are kept.

The Portulaca Family (*Portulacaceæ*). — This family contains one of our most troublesome, garden weeds, the common purslane. It is a “spread-weed,” and one specimen covers considerable space, crowding everything else out. The stems are very succulent and will root very persistently after being hoed out. Its most vulnerable feature is that a very light frost kills it. It is an annual introduced from Europe and produces large numbers of very small seeds.

The Plantain Family (*Plantaginaceæ*). — There are several plantains, and at least two of them, the common plantain and the rib grass, injure lawns or pastures in poorly drained localities. They are destroyed by drainage and cultivation.

There are a number of other plants such as the common buttercups, golden corydalis, wild morning-glory, Norwegian cinquefoil, evening primrose, water parsnip, milkweed, Indian hemp, wild rose, and nettle, that are occasionally troublesome. As a rule, however, they are not persistent.



FIG. 243.—EVENING PRIMROSE IN FRUIT.

SUGGESTIONS. — 1. Methods of controlling weeds, such as proper cultivation, seed selection, rotation of crops, seeding to grass, and keeping stock, belong more properly to agriculture than to botany, and are usually dealt with under that subject. The ability to identify plants and the knowledge of their life history, modes of growth and of seed dispersal, properly belong to botany and should be treated as such.

2. Let the pupils identify every weed mentioned which grows in the district, and study its life history.

3. Collect and examine the seeds of all weeds in the district.

4. Identify any other weeds of the district that give trouble, and find out what characteristics of the plants make them troublesome.

NOTE. — For characteristics of families and detailed descriptions of particular species the pupils are referred to the *Flora* ; also every school should have a copy of "Farm Weeds," published by the Department of Agriculture, Ottawa. The latter gives not only descriptions, but excellent pictures in color of all the most troublesome weeds, and full instructions for treatment.

CHAPTER XXIV

FIELD AND GARDEN CROPS

Grass Family.

The three principal grains produced in Western Canada, wheat, oats, and barley, and also all the grasses used as forage, belong to the Gramineæ or grass family of plants. As this family also includes rice, rye, Indian corn, sugar-cane, and millet, it is no exaggeration to say that from an economic standpoint it is the most important family in the whole vegetable kingdom.

When it is said

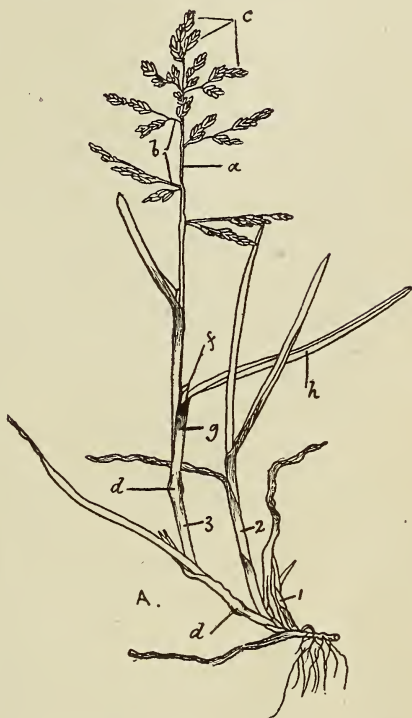


FIG. 244. — A TYPICAL GRASS PLANT, complete.
d, nodes; *g*, leaf-sheath; *f*, ligule; *c*, spikelets; *a*,
rachis; *b*, branches of rachis; *h*, blade.

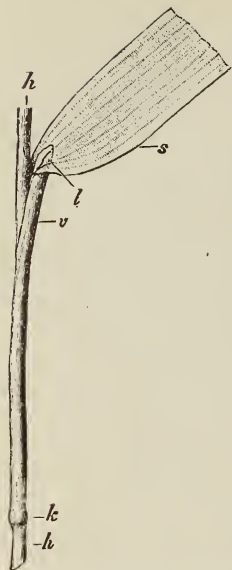


FIG. 245. — PART OF STEM
AND LEAF OF A GRASS.
h, culm; *k*, joint; *v*, sheath;
l, ligule; *s*, blade.

that these plants belong to the same family we mean that they are related and have many characters in common. These common structures possessed by all the cereals and grasses will first be described, and then some of the structures peculiar to each of the more important members of the family.

Figure 244 shows the organs of a typical grass. The root is always fibrous and consists, in the cereals, of many slender fibres which are much branched and very long; such roots are annuals, and die at the end of each year, though in winter wheat the roots continue alive through one winter. Many grasses, such as the meadow and

grasses, have thicker roots, which are perennial and which grow from year to year.

The part of the stem that rises above the ground is always a narrow cylinder of great rigidity called a **culm**. It is hollow in all the members of the family except the Indian corn and the sugar-cane, which have a soft pith at the centre.



FIG. 246. — SPIKELET OF WHEAT
IN FLOWER.

The hollow in the stem is interrupted at regular intervals by transverse partitions called **joints**, and there is usually an external swelling opposite each joint. The tissues of the joint are turgescient and help to erect a stem that has become lodged. Besides this erect part of the stem many grasses have an underground stem which often forms an extended network. These networks are usually perennial and at every joint new stems may shoot up, so that a single plant may spread over a considerable area; the couch-grass, one of our most troublesome weeds, and many grasses suitable for turf or sod are of this character. There is seldom any branching of the culm except just where it leaves the ground; here however a considerable number of culms may spring from a single point, giving it a tufted appearance; oat and barley are examples of this. The culms lengthen out very rapidly when once they begin to grow.

The leaves (Fig. 244 *f*, *g*, *h* and Fig. 245 *s*, *l*, *v*) consist of two main parts, a long, narrow, parallel-veined **blade** (*s*) and a basal **sheath** (*v*) surrounding the culm down to the next joint *k*; the sheath is usually split down its whole length on the side opposite the blade; at the point where the blade and sheath meet is a scale, the **ligule** (*l*) which prevents the rain-water from running down between the sheath and the culm.

The flowers are always arranged in a cluster at the top of the culm (Figs. 254, 260). The flower cluster is always composed of units called **spikelets**, and when these spikelets are sessile on the main stem or **rachis**, as in wheat and



FIG. 247.—DIAGRAMMATIC REPRESENTATION OF A GRASS SPIKELET. *g*, glumes; *p*₁, flowering glume; *p*₂, palea; *B*, flower.

barley, the cluster forms a **spike** (Figs. 249, 258); but when the rachis is branched, as in oats and meadow-grass, the cluster is called a **panicle** (Fig. 254). Figure 246 shows a spikelet of the wheat, and Figure 247 is a diagram showing the parts of a spikelet with the axis much elongated. The spikelet has an axis, upon which is arranged a series of

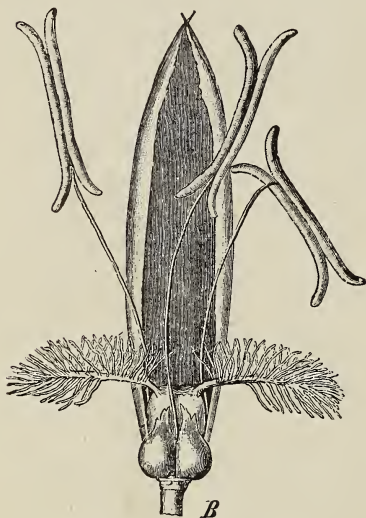


FIG. 248.—FLOWER OF GRASS.

sessile bracts in two opposite rows; the two lowest are called the **empty glumes** (Fig. 247 *g*), as they subtend no flower in their axil; the next glume subtends a flower and is called the **flowering glume** (Fig. 247 *p*₁). It frequently has its mid-rib prolonged into a spine called an **awn** or **beard** as in barley, some oats and wheat. Opposite the flowering glume is another bract called the **palea**

(Fig. 247 *p*₂) and between these two is the flower. The diagram (Fig. 247) shows two other flowering bracts with their flowers and two abortive flowers still higher on the rachis. Several flowers with their bracts are found in most spikelets; wheat usually has three.

The flower itself (Fig. 247 *B* and Fig. 248) consists of three stamens with long filaments and two-celled anthers and a single ovary with two feathery styles. The only

signs there are of floral organs are two small scales around the ovary called **lodicules**. These by swelling cause the glumes to open so that the stamens and stigmas may be



FIG. 249. — *TRITICUM VULGARE*, or common wheat.

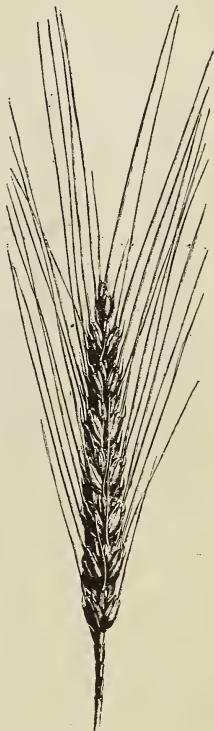


FIG. 250. — *TRITICUM DURUM*, or "Goose" wheat.

extended. The flowers open quite early in the morning and remain open for a short time, so that the casual observer does not usually see them at all. As the flowers

are inconspicuous they are not adapted to insect pollination, but they are beautifully adapted to wind pollination, and it is by this means that fertilization is brought about.



FIG. 251.—TRITICUM SPELTA, or spelt.



FIG. 252.—TRITICUM DICOCCUM, or Emmer.

Self-pollination is the rule in wheat, oats, and barley, but rye and maize must be cross-pollinated to produce good seed.

The ovary contains a single ovule which ripens into a seed, but as it matures the wall of the ovary adheres to the ripened seed to produce the **grain**, thus the grain is not a seed but a fruit, consisting of the mature seed with the adhering **pericarp**. The fruit contains much food material, both nitrogenous and starchy, and is largely endosperm, the embryo being small and placed

at one side of the endosperm; all grasses have a single cotyledon.

The Grasses. — *Wheat.* Wheat has been used as human food for ages, records of its growth having been obtained as far back as five thousand years. There are several species of wheat cultivated in various parts of the world, but only four of them are cultivated in Western Canada,

and two of these only on a very limited scale. These species are as follows:

1st. *Triticum vulgare*, or Common Wheat, such as "Marquis" (Fig. 249).

2d. *Triticum durum*; the well-known "Goose" wheat belongs to this species (Fig. 250).

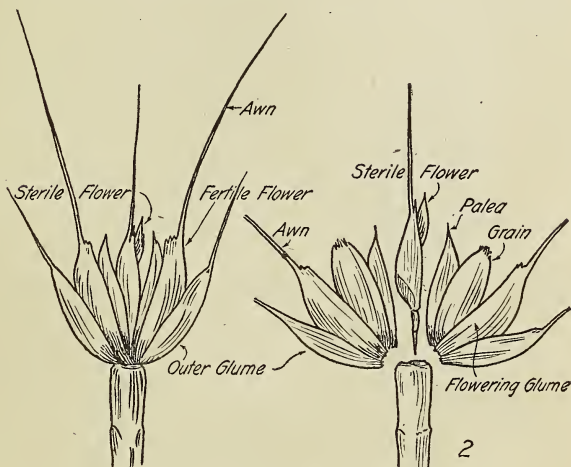


FIG. 253.—SPIKELET OF WHEAT. 1, in flower; 2, ripe.

3d. *Triticum spelta*, or Spelt (Fig. 251).

4th. *Triticum dicoccum*, or Emmer (Fig. 252).

Neither of the two latter species is grown to any great extent in Western Canada, and the grain is used only for feeding. The common wheat is most generally cultivated in the West.

The wheat plant branches at the base, one stem sending out several branches, each of which grows straight up and produces a flower cluster at the top in the form of a spike. Each spikelet (Fig. 253) consists of two or three perfect

flowers, each of which produces a mature grain and one or two abortive flowers at the top. The flowering glumes are usually awned, but the length of the awn varies greatly; where it is long the wheat is bearded and where it is very short the grain is almost beardless. The color of the grain varies from light yellow through amber to red.

There are many varieties of wheat, some adapted to hot

climates, some to cold, some to one kind of soil, and some to another.

The most notable variety used in the West is the "Red Fife," which originated in Scotland. It is

beardless, has a hard, red kernel and makes excellent flour, containing

much nitrogenous material; it is also little

subject to the attacks of disease and insects; it is a little late in maturing

for one short season. "White Fife" is quite



FIG. 254.—PANICLE OF "ABUNDANCE"
OATS.

similar to the "Red Fife" except that the grain is of a light color. "Marquis" wheat is probably the most popular variety in the West at the present time. It is beardless, the glumes or chaff are pure white, the straw is short and it matures from ten to fourteen days earlier than the "Red Fife."

The above varieties are all planted in the spring and harvested in the autumn and are called spring wheats. "Turkey Red" and "Dawson" are two varieties of winter

wheat. They are what are called winter annuals, being planted in the autumn, and after enduring the winter, complete their growth during the next summer.

Oats. This plant prefers a cool, moist climate, and can produce a good crop in the West in some classes of soil, especially in high altitudes, where wheat would not mature. The spikelets are arranged around a central axis, but not in a close spike as in the wheat but in a loose panicle; the two main varieties are distinguished by the shape of this panicle; it may be spreading as in the "Abundance" (Fig. 254) or one sided as in the "Banner" (Fig. 255), both of which are largely grown in the West. The spikelets (Fig. 256) contain two or more flowers, but only two of these produce seed in **twin oats** or only one produces seed in the **single oats**. What is usually called the seed is really the fruit surrounded by the flowering glume and pelea, these two latter being the husks. In this respect it differs from wheat, as in it the husks are removed in the threshing. Oats may be white, yellow, gray, red or black in color, both "Banner" and "Abundance" being white.



FIG. 255.—PANICLE OF "BANNER" OATS.

Barley. Barley is one of the oldest of the cereals, and

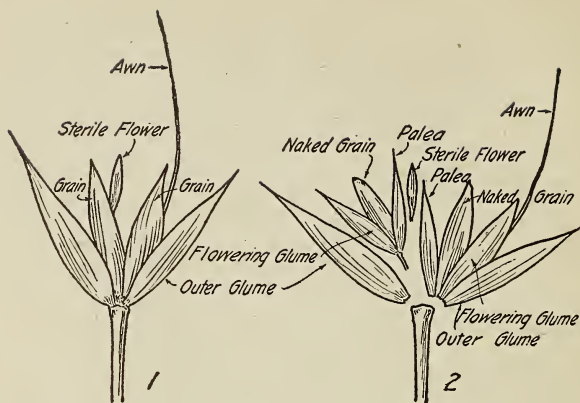


FIG. 256.—SPIKELET OF OATS. 1, in flower; 2, ripe.

was used more largely for bread-making than any other grain up to the sixteenth century. Its roots are not so long or complex as those of oats or wheat, its leaf is

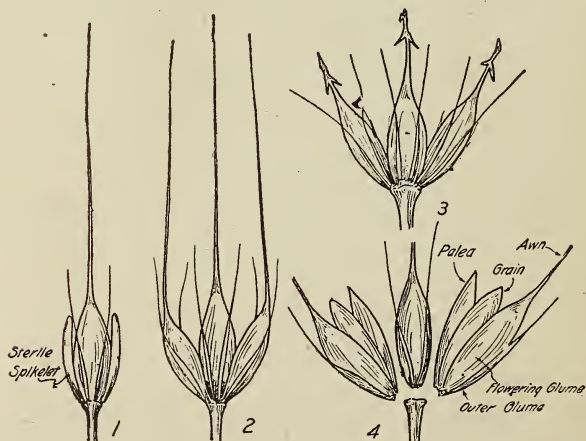


FIG. 257.—SPIKELET OF BARLEY. 1, two-rowed type; 2, six-rowed bearded; 3, six-rowed beardless; 4, dissected spikelet.

broader and the stem does not grow so high. The flowers and fruit form a spike as in the wheat. A central stem passes up and the spikelets come out alternately from op-



FIG. 258.—EAR OF TWO-ROWED BARLEY.



FIG. 259.—EAR OF SIX-ROWED BARLEY.

posite sides. Three sessile spikelets (Fig. 257) spring from the axis at each point. Each spikelet has a single flower. In the two-rowed barley (Fig. 258) only the cen-

tral spikelet produces a fruit, the other two remaining abortive, so that the kernels run along the spike in two opposite rows; in the six-rowed variety (Fig. 259) each of the three spikelets at each node matures a grain, so that the kernels are arranged in six rows along the spike. The empty glumes are small, the flowering glume has a barbed awn from three to six inches long, hence barley is usually



FIG. 260.—INDIAN CORN OR MAIZE. *A*, female spike; *B*, male panicle.

strongly bearded. The flowering glume and pelea adhere very closely to the kernel as husks when the grain is threshed. The adhesion is much more intimate than in oats.

The six-rowed is the most popular variety in the West, the "Mercury" and "Odessa" strains giving the best results.

Barley can be grown over a wider range of climate than any other cereal, for it has been grown successfully from

California to Alaska. It also succeeds at a high altitude. It requires less rainfall than either wheat or oats and less time to mature.

Maize or Indian Corn. This is also a member of the grass family but differs greatly from the other cereals.



FIG. 261.—TIMOTHY. *a*, empty glumes; *b*, flower.



FIG. 262.—WESTERN RYE-GRASS. *a*, spikelet; *b*, *c*, flowering glumes.

Its home is in America, and Columbus found it cultivated by the Indians in Haiti. Besides the ordinary roots it has **brace roots** arising from the nodes above the soil and growing obliquely into the soil. These prevent the heavy stem from being bent over by the wind. The stem, unlike the other members of the family, is solid. The most remark-

able difference is in the inflorescence. It is monoëcious, the flowers with stamens (Fig. 260 *A*) being situated on the top of the stem in a panicle, while the flowers with pistils (Fig. 260 *B*) form a lateral spike surrounded by leafy bracts situated in the axil of a leaf. The staminate



FIG. 263. — AUSTRIAN BROME-GRASS.
a, spikelet; *b*, *c*, flowering glumes.

spikelet has two empty glumes within which are two flowers each with three stamens. When the latter are mature the filaments become very long and flexible so that the anthers hang down and shake the copious pollen out, where it is transferred by the wind. The pistillate flowers on the cob are in pairs, but one pistil of each pair is abortive, the other has a long hair-like style projecting out of the top of the ear; the collective, silky hairs from all the pistils form the hairy tassel projecting from

the top of the ear. This plant is very sensitive to cold and frost and does not mature in the West, but is cut green and used as forage for the stock.

The Grasses.—The three most abundant grasses produced for fodder in the West are timothy, western ryegrass and Austrian brome-grass.

Timothy (Fig. 261) grows in a tuft of culms from a

single basal stem; it is unbranched above and the flowers grow in what appears to be a long, cylindrical spike, but on close examination it will be seen that the spikelets are not sessile, so that it is really a closely compressed panicle. Each spikelet has only a single flower (*b*), and the awn (*a*) is very short on the empty glume and absent on the flowering glume. It is a perennial.

Western rye-grass (Fig. 262) is a perennial, which grows wild in Western Canada but it is now also under cultivation for over twenty years. The flower cluster is a slender spike with the compressed spikelets attached alternately to the zigzag axis on opposite sides. Each spikelet has numerous flowers (*a*).

Austrian brome-grass or Hungarian brome-grass (Fig. 263) is a native of the steppe of Europe. It

is a tall grass, reaching 5 feet in height and has leaves one-half inch wide. The flowers form a loose panicle. It will thrive under a lighter rainfall than either of the other two varieties.

Millet (Fig. 264). This grass has been cultivated from very ancient times. While in Europe it is cultivated for its grain, in Canada and the United States it is used as



FIG. 264. — MILLET. *a*, *b*, spikelets; *c*, flowering glume.

a forage crop. It is a stout, erect annual from three to eight feet high. The flower cluster is in the form of a panicle that is so compact that it resembles a spike. The spikelets are intermingled with bristles.



FIG. 265.—ROOT OF A
LEGUMINOUS PLANT
SHOWING NODULES.

Leguminous Plants. — These are plants which belong to the pea family. They possess the peculiar power of taking the free nitrogen from the air and combining it with other elements to build up the plant tissues. This power is given by bacteria found in small swellings, called **nodules** (Fig. 265), on the roots. If these bacteria are absent from the soil the plants will not reach their fullest development. This property enables leguminous plants to be grown on soil which is poor in nitrogen compounds and their decaying roots add plant-food to the soil.

The bean, pea, vetches, lupines, and all the clovers are members of this family. Alfalfa (Fig. 266) or lucerne is by far the most important of these in the West. It has a tap-root of great length, which ordinarily penetrates the subsoil to a depth of six feet and sometimes reaches to a depth of fifteen feet or more. It is thus able to obtain moisture from a great depth, and can consequently thrive in a semiarid region. As the root is perennial, one sowing will give crops for a number of years. The leaves are compound, having three leaflets; if they are observed, it

will be seen that their positions during the day and night are quite different. The purple flowers are in long racemes. Each flower has five united sepals, and a peculiar corolla shown in Fig. 172. There are ten stamens (*T*), nine of them



FIG. 266. — ALFALFA OR LUCERNE.

united by their filaments and one quite separate. The pistil is a pod (*Y*) with a stigma at the end. The method of pollination in this plant is quite remarkable. When a large bumblebee alights on the petals, the stamens and

pistil, which are in a state of tension, spring up like a trigger (Fig. 172, dotted line) and dust the bee on the under surface with pollen, and this is transferred to the stigma of the next flower visited. A small bee is not heavy enough

to set off this trigger, and if the trigger is not set off, few or no seeds set. Thus the amount of seeds produced by alfalfa is dependent on the abundance of bumblebees in the district.

Flax. — The flax plant is grown extensively in the West, as it is a short-season crop and can be planted after all the other seeding is completed. This plant is grown either for the fibre or for the seed. In Canada and the United States it is grown largely for the seed, while in Europe it is grown primarily for the fibre. When grown for the latter purpose the seed is planted close together so that a long, straight, unbranched stem (Fig. 267 *B*) may be produced and from



FIG. 267. — FLAX. *A*, grown for seed; *B*, grown for fibre.

this long fibres are obtained, and when grown for seeds it is planted thinly so that the stem branches greatly (Fig. 267 *A*) and produces many seed pods.

The root system of the plant is quite small, consisting of a weak tap-root and a few lateral branches. The stem has the bast in the fibro-vascular bundles strongly de-

veloped and it is these hard bast fibres that are separated from the woody and other tissues to make linen fibres. The flower (Fig. 268) is quite large with beautiful blue or white petals. The sepals are five in number, the poly-petalous corolla also consists of five petals; there are ten stamens, and a five-celled ovary with five styles. Each



FIG. 268.—FLAX. 1, flower; 2, stamens; 3, cross-section of pistil; 4, fruit.

ovary-cell ripens two seeds, so that each seed pod contains ten seeds. The greenish-brown seeds are of a lenticular shape and when moistened the epidermal cells become mucilaginous. They contain much oil, which is extracted as linseed-oil and is largely used in paints; the crushed seeds are used as food for stock.

Field Roots.—The chief field roots grown are Swedish turnips, mangolds, and field carrots. These all belong to different families of plants, but have this character in common, viz., they are all biennials. The seed is planted in the spring and a plant is grown by the end of the first year that has a large tap-root, with a tuft of leaves growing from

the top of it; the stem is practically absent. The large tap-root is a storage place for nourishment reserved for the second year's growth. During the second year, if the plant is not destroyed by the frost, a leafy stem shoots up that produces flowers and fruit, the tap-root shrinking as the nourishment is extracted from it. At the end of the season the whole plant dies.

SUGGESTIONS. —

1. Soak grains of barley, oats, wheat and corn in warm water for six hours, then examine them, finding the seed coats, endosperm and embryo. Notice that the first two have two husks on them.

2. Examine seedlings of each of the plants mentioned in 1. Find what characters they have in common, and in what respects they differ..

3. Learn to distinguish young plants of each of the cereals; in your walks endeavor to identify all the grain crops produced in the section in which you live.

4. Examine all the cereals of your section when they are coming in ear to find specimens with the stamens extruded. Study the structure of the flower cluster with the help of the illustrations and descriptions given in this chapter.

5. Examine the ripened ears of the cereals; determine to which variety each belongs. Examine the spikelets to find their structure.

6. Pull up an alfalfa plant from softened soil, wash off the adhering earth and try to find the nodules. Any other leguminous plants, as clover, beans, peas, or vetches should be examined in the same way.

7. Find in the meadows or hay-fields timothy, rye-grass, brome-grass, and millet: study their structure with the assistance of the descriptions and illustrations given in this chapter.

GLOSSARY

- accessory* or *reinforced fruits* are those in which the ripened pericarp is combined with other parts, as with the torus or the calyx.
- adventitious*. Coming by chance or without order, as the sprouts that arise where a limb is cut off.
- aggregate fruits* are those in which several distinct pistils cohere to form one body, as in blackberry, raspberry, mulberry.
- akene* or *achene*. A one-seeded indehiscent fruit, usually small and seed-like.
- analogous*. Like to, in function or use. See *homologous*.
- anemophilous*. Said of flowers that are pollinated by the wind.
- annual*. A plant that naturally does not live more than one year, as garden bean, pea, Indian corn, buckwheat, cowpea.
- anther*. The knob or enlargement of the stamen, bearing the pollen.
- antheridium*. The male or sperm-cell organ, such as occurs on the prothallus of ferns and similar plants. See *archegonium*.
- apetalous*. Without petals.
- apical*. At the top.
- archegonium*. The female or egg-cell organ on the prothallus of ferns and related plants. See *antheridium*.
- assimilation*. The building up of protoplasm from the materials elaborated in the plant.
- axil*. The angle or place just above the petiole of a leaf (or pedicel of a flower) where it joins the twig.
- berry*. In botany, a fleshy pericarp containing a number of seeds, as current, orange, tomato, grape, cranberry, but not strawberry, blackberry, raspberry, or mulberry.
- biennial*. A plant that lives two years. It usually blooms the second year.
- blade*. The expanded part of a leaf.
- bract*. A small or much-reduced leaf, often a mere scale.
- calyx*. The outer row or series in the floral envelope. The outer "leaves" of the flower, usually green.
- cambium*. Growth tissue, lying between the bark-part and wood-part of the fibro-vascular bundle and giving rise to the cells of both.

- capsule*. A pod consisting of two or more carpels or parts, usually opening naturally.
- carbohydrate*. The compounds of the starch and sugar class.
- carpel*. One part or member of a compound pistil, or a simple pistil itself.
- catkin or ament*. A raceme-like or spike-like flower-cluster that falls away after flowering or fruiting, as of willows and staminate flower-clusters of walnuts and birches.
- centrifugal*. From the inside out; as a flower-cluster of which the inside, terminal, or uppermost flowers open first; a determinate cluster.
- centripetal*. From the outside in; as a flower-cluster of which the outer flowers open first; an indeterminate cluster.
- chlorophyll*. Leaf green. Chlorophyll is the pigment that gives the characteristic color to plants.
- cladophylla*. Stems that look like leaves, and function as leaves, as in asparagus and the florists' smilax.
- cleistogamous*. Applied to small flowers, usually hidden beneath the earth, that are little developed as to floral envelopes, and are self-fertilized; also to self-fertilization in flowers that do not open.
- complete flowers* have all the parts, — calyx, corolla, stamens, pistil.
- corolla*. The inner row or series of flower-leaves, usually colored, and often of irregular shape. It may be all one piece or of many pieces.
- corymb*. A flattish flower-cluster in which the outermost flowers open first.
- cotyledon*. A leaf of the embryo; seed-leaf. The embryo may have one cotyledon (monocotyledon), or two cotyledons (dicotyledon), or sometimes more than two.
- cross-fertilization* is fertilization by means of pollen produced in another flower.
- cryptogam*. One of the group of flowerless or non-seed-bearing plants, as a fern, fungus, moss, seaweed.
- cutting*. A shoot planted in soil or water for the purpose of making a new plant.
- cyme*. A flattish or broad flower-cluster in which the innermost or terminal flowers open first.
- decumbent*. Said of branches or stems that lop or lie over on the ground.
- decurrent*. Said of a leaf that runs down on the stem, thereby not having a distinct petiole.
- dehiscence*. The mode of opening, as of a seed-pod or an anther.

deliquescent. Said of trees in which the leader or main trunk disappears at the tree-top, forking into several or many main branches.

determinate. See *centrifugal*.

dichogamy. The condition when stamens and pistils in the same flower mature at different times; this prevents or hinders self-pollination. See *proterandrous* and *proterogynous*.

diclinous. Said of flowers that are imperfect, — lacking either stamens or pistils.

dicotyledon. Having two cotyledons or seed-leaves.

digestion. Change in the food materials whereby they may be transported, or used in assimilation. Starch is changed into sugar in the plant by a process of digestion.

dimorphous. Of two forms; as flowers that bear two kinds of stamens.

diœcious. Said of plants that bear stamens and pistils in flowers on different plants.

drupe. A fleshy pericarp or fruit, containing a relatively large stone or pit, as peach, cherry, plum.

drupelet. A very small drupe, particularly one comprising part of an aggregate fruit, as a drupelet of raspberry.

× *embryo*. The dormant plantlet comprising part of the seed. It is enclosed within the seed-coats. Its parts are the caulicle (or stemlet), cotyledons or seed-leaves, and plumule. The food may be stored in the embryo, or around the embryo (endosperm).

endogen. A plant of the monocotyledon class, not enlarging in diameter by means of outside rings; as palms. All grasses and lilies and orchids and cereal grains are of this kind. Now used, if at all, to express a general mode of growth rather than a class of plants. See *exogen*.

endosperm. The food material that is packed around the embryo (rather than inside it) in the seed.

entomophilous. Said of flowers that are pollinated by insects.

environment. The surroundings; or the conditions in which a plant or animal lives. The environment comprises the soil, climate, and the influence of the other plants and animals with which or among which the plant or animal grows.

epicotyl. The internode or "joint" above the seed-leaves or cotyledons.

epidermis. The outermost layer or part of the cortex; the skin.

epigeal. Said of seeds (as common bean) in which the cotyledons or seed-leaves rise above ground in germination. See *hypogeal*.

epiphyte. A plant that grows on another plant, or on other objects above ground, but which does not derive much or any of its nourishment from its host; an air-plant.

- excurrent.* Said of trees (as firs and spruces) in which the main trunk or leader continues through the tree-top.
- exogen* (see *endogen*). Of the dicotyledon class, the stem enlarging by external layers or rings.
- fertilization* takes place in the flower when a pollen nucleus and an egg-cell nucleus unite in a forming ovule.
- fibro-vascular.* Bundles or strands of tissue composed of sieve tubes, mechanical fibre, and vessels or ducts.
- filament.* The stalk part of a stamen.
- follicle.* A single-cavity fruit or pod opening along its inner edge.
- frond.* A leaf of a fern and related plants.
- fruit.* In botany, the ripened ovary with the attached parts. All flowering plants, therefore, produce fruits. The term is also used for the ripened reproductive bodies of flowerless plants.
- fruit-dot, sorus.* A collection or cluster of sporangia, as in ferns.
- function.* What a plant or an organ does; how it works.
- gamete.* A cell or nucleus that takes part in fertilization.
- gametophyte.* The stage of the plant (as the prothallus) that bears or produces the sex organs; sexual stage of the plant.
- gamopetalous.* Said of a corolla with the petals united.
- gamosepalous.* Said of a calyx with the sepals united.
- generation.* The entire life period of a plant.
- geotropism.* Turning towards the earth, as the action of the roots.
- glomerule.* A dense globular or oblong flower-cluster in which the upper or inner flowers open first.
- graft.* A cutting inserted in another plant for the purpose of having it grow there.
- gymnosperm* ("naked seed"). A name applied to a group of plants (pines, spruces, cedars, and the like) in which the seeds are not contained in an ovary.
- head.* A very dense globular or oblong flower-cluster in which the outer flowers open first; often applied to any dense flower-cluster.
- herb.* A plant that never becomes woody and that dies to the ground, or dies entirely, in winter.
- hilum.* The scar or spot where the seed was attached to its stalk.
- hip.* The fruit of the rose, which is a hollowed torus containing the dry fruits or "seeds."
- homologous.* Related to, or with, in origin or structure. Thus, a tendril of grape is homologous with a branch; a tendril of grape is *analogous* to a tendril of pea (similar in function), but not homologous, for one represents a branch (or flower-cluster) and the other represents a leaf.

- host*. A plant or animal on which another organism grows or feeds.
- hypha* (plural *hyphæ*). The threads of the mycelium of a fungus.
- hypocotyl*. The stem or internode below the seed-leaves.
- hypogeal*. Said of seeds (as garden pea) in which the cotyledons remain under ground in germination. See *epigeal*.
- imperfect flowers* lack either stamens or pistils.
- incomplete flowers* lack one of the parts or series, as the calyx, corolla, stamens, or pistil.
- indeterminate*. See *centripetal*.
- indusium*. The scale or lid covering a sorus, in ferns and allied plants.
- inflorescence*. Properly, the mode of flowering, but sometimes used in the sense of a flower-cluster.
- involucre*. A set or whorl of leaves or bracts beneath a flower or a cluster of flowers; sometimes looks like an outer or extra calyx.
- irregular flowers* have some members of one or more of the series unlike their fellows.
- key fruit*. See *samara*.
- labiate*. Lipped; that is, divided into parts, as the lips of a mouth. Said usually of corollas that are lobed into two parts.
- lateral*. On the side; as a flower or leaf borne on the side of a shoot rather than at its end. See *terminal*.
- leaflet*. One of the divisions or parts of a compound leaf.
- legume*. Like a follicle, but opening along both edges. In some cases, as in peanut, the pod does not actually open.
- leguminous plants* are those that bear legumes or true pods, as peas, beans, clovers, alfalfa, vetch, sweet pea, peanut, locusts, red-bud.
- lenticel*. Very small spots or corky elevations on young twigs, marking the place of former twig stomates.
- locule*. One cavity or "cell" in a pistil or anther.
- loculicidal*. Said of capsules when the carpels or compartments open between the partitions.
- mesophyll*. The parenchyma in the leaf.
- microphyle*. The place on the seed at which the pollen-tube entered when the seed was forming (when impregnation took place).
- monocotyledon*. Having one cotyledon or seed-leaf.
- monœcious*. Said of plants that bear the stamens and pistils in different flowers on the same plant.
- mycelium*. The vegetative part of a fungus, composed of threads or hyphæ.
- mycorrhiza*. A root covered with or bearing a fungus that aids the root in securing nourishment from the soil.
- naked*. Said of flowers that lack envelopes (calyx and corolla).

nectary. A cup, sac, or place in the flower in which nectar (or "honey") is borne.

osmosis. The passing or diffusion of liquids or gases through membranes.

ovary. The lower enlarged part of the pistil, containing the ovules or forming seeds.

ovule. The young or forming seed.

palmate. Palm-like; said of venation that arises from the base of the leaf (top of petiole), or of leaflets similarly arranged.

panicle. A branching raceme. The lower or outer flowers open first; but the word is often used loosely.

pappus. The hair, plumes, bristles, or scales on the top of a dry fruit, particularly of a fruit (or "seed") of the Compositæ or sunflower family.

parasite. A plant or animal that lives on a living host (as on a plant or an animal), taking its food from the host. See *saprophyte*.

parenchyma. The general underlying tissue, from which other tissue arises. (Word not derived from *parent*.)

pedicel. Stem of a single flower in a cluster.

peduncle. A flower stem, supporting a solitary flower or a cluster of flowers.

perennial. A plant that lives more than two years, as most grasses, docks, alfalfa, asparagus, and all trees and shrubs.

perfect flowers bear both stamens and pistils.

pericarp. A ripened ovary, without counting attached parts.

personate. Masked; that is, so formed as to suggest a masked face, in labiate corollas with a large lower lip.

petal. One of the parts or leaves of the corolla.

petiole. Stem or stalk of a leaf.

petiolule. Stem of a leaflet.

phenogam (*phænogam*, *phanerogam*). A seed-bearing plant; that is, one of the seed-bearing or flowering group of plants.

phloem. Bark or soft bast tissue.

photosynthesis. The process whereby the carbon dioxide of the air is appropriated in the formation of material for plant growth.

phyllotaxy. Mode of arrangement of leaves or flowers on the plant or stem.

pinnate. Feather-like; said of leaves in which the veins strike off from a continuing midrib, or in which the leaflets are arranged in a similar order.

pistil. The innermost member in the flower, bearing the forming seeds.

pistillate. Of pistils only; a flower that contains pistils and no stamens, or a plant that bears only pistils.

- plur-annual*. A plant of a tropical or semi-tropical climate that is annual in a colder country only because it is killed by frost; as tomato, castor-bean.
- pollen*. The dust or grains contained in the anther and which, falling on the stigma, grows and fertilizes the forming ovules.
- pollination*. The transfer of pollen from the anther to the stigma. The transfer may be accomplished by wind, insects, birds, water (in the case of water plants), or by the natural falling of the pollen.
- polypetalous* ("many-petalled"). Said of a corolla with the petals not united.
- polysepalous* ("many-sepalled"). Said of a calyx with sepals not united.
- pome*. An apple-like or pear-like or quince-like fruit, with a five-carpeled or ten-carpeled "core."
- proterandrous*. Said of a flower when the anthers mature in advance of the pistils in the same flower.
- proterogynous*. Said of a flower when its pistils mature before its anthers.
- prothallus* ("first thallus"). The minute leaf-like body or organ produced by the germination of a spore, in ferns and allied plants. It bears the sex organs.
- + *protoplasm*. The living matter in plants. It is the living part of the cells, usually in a semi-fluid, translucent state.
- pseud-annual*. A plant that is apparently annual, but which is carried over winter by a bulb, tuber, or similar body; as potato, onion.
- pyxis*. A dry fruit or capsule in which the top comes off, like a cover to a jar.
- raceme*. A simple (unbranched) cluster in which the flowers are on short pedicels and open from the base upwards.
- raphe*. A ridge or elevation on some seeds caused by the seed-stalk and seed-coats growing together.
- ray*. The elongated corolla-limb of some members of the Compositæ family.
- X *receptive*. Said of a stigma when it is "ripe" or ready to receive the pollen.
- regular flowers* are those in which all the members of each series (as all the sepals, or all the petals, or all the stamens) are like each other in shape, size, and color.
- reinforced*. See *accessory fruits*.
- respiration*. Breathing; manifest by oxygen taken in and carbon dioxide given off.
- rhizome*. A rootstock; an underground root-like stem. It has joints, usually scales representing leaves, and is often thick and fleshy.

- samara*. A key fruit, being an indehiscent (not opening) fruit provided with a wing or wings.
- saprophyte*. A plant that lives on dead or decaying material. See *parasite*.
- scape*. A flower-stem rising directly from the crown of the plant at the surface of the ground or near it. A scape may have bracts.
- self-fertilization* or *close-fertilization* is fertilization by means of pollen produced in the same flower.
- sepal*. One of the parts or leaves of the calyx.
- septicidal*. A form of dehiscence or opening along the natural partitions of the capsule.
- sessile*. Sitting; without a stem, as a leaf without petiole, or a flower without pedicel or peduncle.
- shrub*. A low, woody plant that does not have a distinct trunk. When a plant normally has a trunk, it is a tree.
- silicle*. A short, more or less circular, capsule of the mustard family.
- siliqua*. A long capsule of the mustard family.
- society*. An aggregation or company of plants, comprising a more or less distinct group.
- sorus* (plural *sori*). See *fruit-dot*.
- spadix*. A spike of flowers (each flower usually minute), with a more or less fleshy axis, and usually accompanied by a spathe.
- spathe*. A corolla-like or involucre-like leaf or bract (or a pair of them) surrounding or accompanying a spadix. In the calla, the spathe is the large white flower-like part.
- spermaphyte* ("seed plant"). A seed-bearing plant; one of the flowering-plant class.
- spike*. A dense and slender flower-cluster in which the flowers open from below upwards.
- sporangium* (plural *sporangia*; *spore-case*). A body or receptacle holding spores.
- spore*. A reproductive or generative cell; in flowerless plants answering the purpose of a seed, but containing no embryo. It may not be the direct product of fertilization.
- sporophyll* ("spore leaf"). A member or part that bears spores.
- sporophyte*. The stage of the plant arising directly from the fertilized egg, and which ordinarily produces asexual spores (as the "plant" or conspicuous part of the fern or of a seed-plant).
- stamen*. The pollen-bearing organ of the flower, of which the essential part is the anther (usually borne on a stem or filament).
- staminate*. Said of a flower that has stamens and no pistils.
- stigma*. The part of the pistil (usually on a stalk or style) on

which the pollen germinates; it is sticky, rough, or hairy at maturity.

stipel. A stipule of a leaflet.

stipule. A leafy or scale-like appendage at the base of a petiole. Stipules are usually two in each case.

stomate, stoma (plural *stomates* or *stomata*). The openings on leaves and green parts through which gases pass; diffusion-pores or "breathing-pores."

stone-fruit. A drupe.

strict. Said of a stem that grows straight up, without breaking into branches.

style. The stalk between the ovary and stigma; sometimes not present.

syngenesious. Said of anthers when they cohere in a ring, as in the Compositæ, the style usually being enclosed.

tap-root. A single or leading strong root that runs straight down into the earth.

tendril. A slender coiling member of a plant that enables it to climb. A tendril may represent a branch, a petiole, a leaflet, a stipule, an entire leaf.

terminal. At the end; as a flower borne on the end of a shoot. See *lateral*.

thyrses. A compound, usually elongated or pyramidal flower-cluster in which the mode of inflorescence is mixed.

torus. The end of the flower-stalk (usually somewhat enlarged) to which the flower-parts are attached; receptacle.

transpiration. Evaporation or loss of water from plants.

umbel. A flower-cluster opening from the outside, in which the branches or stems arise from one place, as the rays of an opened umbrella.

umbellet. A small umbel, comprising part of a larger or compound umbel.

valve. One of the integral parts into which a fruit or an anther naturally splits, or into which it is divided.

venation. The mode or fashion of veining, as in a leaf or petal.

xylem. Wood tissue.

INDEX

- “Abundance” oats, 189.
- Accessory fruit, 160, 164.
- Adaptation to environment, 6.
- Adventitious roots, 36; buds, 114.
- Aerial roots, 34.
- Aggregate fruit, 164.
- Air plants, 35.
- Akenes, 160.
- Alfalfa, 197.
- Amaranthaceæ, 176.
- Amaranth family, 176.
- Anemophilous, 145.
- Annual plant, 17.
- Annual sow thistle, 177.
- Annual weeds, 173.
- Anther, 131, 140.
- Apical dehiscence, 162.
- Arum family, 136.
- Ash, 92.
- Assimilation, 97.
- Aster, 177.
- Atriplex, 175.
- Austrian brome-grass, 195.
- Awn, 184.
- Axil, 112.
- Axis, plant, 15.
- Bacteria, 39, 109.
- Ball mustard, 176.
- “Banner” oats, 189.
- Bark, 54, 66, 67.
- Bark-bound trees, 54.
- Barley, 189, 192.
- Bast, 61, 66.
- Bean, 20, 28, 39.
- Beard, 184.
- Berry, 163.
- Biennial plant, 17.
- Biennial weeds, 174.
- Biennial wormwood, 177.
- Black bindweed, 177.
- Blade, 183.
- Bladder campion, 178.
- Blue bur, 178.
- Blue joint, 174.
- Borage family, 178.
- Boraginaceæ, 178.
- Brace cells, 67.
- Bracts, 130.
- Branch, 111.
- Breeding, plant, 7, 8.
- Brome-grass, 195.
- Buckywheat family, 177.
- Buckwheat, wild, 177.
- Budding, 123.
- Buds, 111; flower, 114; fruit, 114.
- Burdock, 177.
- Bur marigold, 177.
- Burs, 168, 170.
- Cabbage, 113.
- Callus, 56.
- Calyx, 129.
- Campion, bladder, 178.
- Cambium, 63, 65.
- Canada thistle, 177.
- Capsule, 162.
- Carbohydrate, 95.
- Carbon, 92.
- Carbon dioxide, 22, 93, 106.
- Carnivorous, 99.
- Carpel, 132.
- Carrot, 7.
- Caryophyllaceæ, 178.
- Castor bean, 24.
- Catchfly, 178.
- Catkin, 154.
- Caulicle, 20, 22, 25.
- Cell, 42, 63, 141.
- Charlock, 176.
- Chenopodiaceæ, 175.
- Chickweed, 178.
- Chlorophyll, 86, 94, 101.
- Cladophylla, 100.
- Cleft leaf, 75.
- Cleistogamous, 147.
- Climbing plants, 125.
- Clover, 39.
- Cluster, flower, 151, 155; centri-fugal, 152, 155; centripetal, 152; indeterminate, 152.
- Cockle, 178; cow, 178; purple, 178; white, 178.
- Colonies, plant, 11.
- Common ragwort, 177.
- Common wheat, 187.
- Compositæ, 176.
- Composite flowers, 136.
- Cone-flower, 177.
- Cork, 66, 67.
- Corn, 3, 25, 26; Indian, 193.
- Corolla, 129; funnellform, 135; labiate, 135; personate, 135; rotate, 135; salver form, 135.
- Cortex, 44.
- Corymb, 155.
- Cotyledon, 20.
- Couch-grass, 174.
- Cow cockle, 178.
- Cruciferæ, 176.
- Culm, 182.
- Currant, 153.
- Cuttings, 119, 121, 122.
- Cyme, 156, 157.
- Dandelion, fall, 177.
- Darnel, 175.
- “Dawson” wheat, 188.
- Deciduous, 82.

- Decumbent, 50.
 Dehiscence, 142, 160.
 Deliquescent, 51.
 Dependent plants, 106.
 Dichogamy, 142.
 Dicotyledon, 20.
 Dicotyledonous stems, 61.
 Digestion, 95.
 Digitate, 74.
 Dimorphous, 145.
 Dioecious, 134, 166.
 Dispersal of seeds, 168.
 Dissection, 30.
 Docks, 177.
 Dodder, 35, 106.
 Drupe, 163.
 Drupelet, 163.

 Ecology, 14.
 Embryo, 20.
 Emmer, 187.
 Empty glumes, 184.
 Endodermis, 44.
 Endosperm, 21, 24.
 Entomophilous, 144.
 Environment, 6.
 Epicotyl, 23, 25.
 Epidermis, of leaf, 86, 87.
 Epigeal, 23.
 Epiphyte, 35, 109.
 Essential organs, 131.
 Excurrent, 51.
 Explosive seeds, 168.

 Fall dandelion, 177.
 False flax, 176.
 Fertilization, 140; cross, 140, 142;
 self, 141, 143.
 Fibro-vascular bundles, 61, 90.
 Field study, 3, 6, 8, 14, 19, 27, 46,
 57, 71, 84, 91, 101, 110, 116, 128,
 139, 148, 168.
 Filament, 131.
 Flax, 198, 199.
 Floral envelopes, 129.
 Florets, 136.
 Flower, 129; apetalous, 132; c'us-
 ters, 151; complete, 132; diclin-
 ous, 133; double, 138; imperfect,
 133; incomplete, 132; lateral,
 132; naked, 132; perfect, 133;
 pistillate, 133; regular, 134;
 staminate, 133; sterile, 133;
 solitary, 152; terminal, 152.
 Flowering glumes, 184.
 Foliage, 16.
 Follicle, 161.
 Forestry, 68.
 Framework of plant, 15.
 Fruit, 159.
 Fungus, 107, 108.

 Gamopetalous, 130.
 Gamosepalous, 130.
 Generation of plants, 16.
 Geotropism, 45, 47.
 Germination, 22, 23, 27.

 Glomerule, 156.
 Glumes, empty, 184; flowering,
 184, .
 Golden aster, 177.
 Golden-rod, 177.
 Goosefoot family, 175.
 Goosefoot, maple-leaved, 175; oak-
 leaved, 175.
 Goose-grass, 177.
 Goose wheat, 187.
 Grafting, 123.
 Grain, 186.
 Gramineæ, 174.
 Grass family, 174, 181, 194.
 Gray tansy mustard, 176.
 Green tansy mustard, 176.
 Grit cells, 67.
 Guard cells, 88.
 Gymnosperm, 26, 165.

 Hairs, 87.
 Hare's ear mustard, 176.
 Haustoria, 107.
 Hawk-weed, orange, 177.
 Herb, 17.
 Hilum, 21, 26.
 Hip, 164.
 Hollyhock, 143.
 Homologous, 130, 131.
 Host, 107.
 Hungarian brome-grass, 195.
 Hyphæ, 107.
 Hypocotyl, 22.
 Hypogeal, 23.

 Indehiscent, 164.
 Indian corn, 193.
 Inflorescence, 156.
 Injury by weeds, 172.
 Internode, 52.
 Involucre, 137, 159.
 Iron, 39.

 Joints, 183.

 Key fruit, 160.
 Knot-weed, 177.

 Laboratory, 3.
 Lamb's quarters, 175.
 Landscape, 13.
 Larkspur, 144, 145.
 Latex tubes, 67.
 Leaf, apex of, 80; base of, 80;
 function of, 92; margin of, 80;
 structure, 86.
 Leaf scar, 90.
 Leaves, arrangement of, 82;
 shapes of, 78, 85.
 Legume, 161.
 Leguminous plants, 196.
 Lenticel, 89.
 Ligneous, 17.

- Ligule, 183.
 Lobes of leaf, 75.
 Locule, 132, 159, 161.
 Loculicidal dehiscence, 162.
 Lodicules, 185.
 Lucerne, 197.
 Lumber, 68.

 Maize, 192.
 Marquis wheat, 187, 188.
 Medullary ray, 64.
 "Mercury" barley, 192.
 Mesophyll, 86.
 Micropyle, 21, 26.
 Microscope, 21, 26.
 Midrib, 77.
 Millet, 195.
 Mint family, 139.
 Monocotyledons, 20, 25, 61.
 Monœcious, 134, 146, 165.
 Moss, Spanish, 110.
 Mullein, 87.
 Muscadine, 36.
 Mushroom, 107.
 Mustard, family, 176; tumbling,
 176; wild, 176.
 Mycelium, 107, 108.
 Mycorrhiza, 108.

 Natural selection, 8.
 Nectar, 148.
 Nitrogen, 39, 40.
 Nodes, 20, 52.
 Nodules, 39, 40, 196.
 Notebooks, 3.
 Nucleus, 140.
 Nuts, 159.

 Oats, 189.
 Odessa barley, 192.
 Oleander, 86.
 Orange hawk-weed, 177.
 Orchid, 35, 110.
 Osmosis, 42, 48.
 Ovary, 131, 140, 159, 165.
 Overgrowth, 12.
 Ovule, 140.
 Ox-eye daisy, 177.

 Palca, 184.
 Palisade cells, 86.
 Palmate, 74.
 Panicle, 154, 184.
 Pappus, 137.
 Parasites, 107.
 Parenchyma, 60, 86.
 Pedicel, 156.
 Peduncle, 156.
 Peltate, 77.
 Peppergrass, 176.
 Perennial, 17.
 Perennial weeds, 174.
 Pericarp, 160, 165, 186.
 Petals, 130.
 Petiole, 76.
 Petunia, 152.

 Photo-synthesis, 94, 101.
 Phyllotaxy, 84.
 Pigweed, 175; Russian, 175.
 Pine cone, 27.
 Pink family, 178.
 Pinnate, 74.
 Pinnatifid, 76.
 Pistil, 131.
 Plantaginaceæ, 179.
 Plantain, 153.
 Plantain family, 179.
 Plant societies, 9.
 Plants, unlikeness of, 9.
 Plumule, 20, 23, 25.
 Plur-annual, 18.
 Pod, 160.
 Pollen, 131, 140.
 Pollination, 140, 141; artificial,
 149.
 Polygonaceæ, 177.
 Polypetalous, 130.
 Polysepalous, 130.
 Pome, 165.
 Portulaca family, 179.
 Prairie thistle, 177.
 Propagation by buds, 119.
 Prop-roots, 36.
 Proterandrous, 142.
 Proterogynous, 142.
 Protoplasm, 42, 94, 97.
 Pruning, 105.
 Pseud-annual, 18.
 Purple cockle, 178.
 Purslane, common, 179.
 Pyxis, 162.

 Quack-grass, 174.
 Quarter-sawed, 70.

 Rachis, 183.
 Ragwort, common, 177.
 Receptacle, 130, 159.
 "Red Fife" wheat, 188.
 Respiration, in plants, 97, 103.
 Rhizome, 52.
 Rib grass, 179.
 Root cap, 44.
 Root climber, 125.
 Root hairs, 41, 42, 46.
 Rootlet, 41.
 Root pressure, 99, 104.
 Roots, and air, 41; forms of, 32;
 function, 38; structure, 38, 43;
 systems, 32.
 Russian pigweed, 175.
 Russian thistle, 175.
 Rye-grass, western, 195.

 Samara, 160.
 Sap, 67.
 Saprophyte, 107, 108.
 Scape, 158.
 Scramblers, 125.
 Seed, 20, 159; coat, 21.
 Selection, natural, 8; artificial, 8.
 Sepal, 165.
 Septicidal dehiscence, 162.

- Sessile, 76.
 Sheath, 183.
 Sheep sorrel, 177.
 Shephard's purse, 176.
 Shrub, 19.
 Sieve tubes, 66.
 Selicle, 162.
 Siliqua, 162.
 Single oats, 189.
 Six-rowed barley, 192.
 Skunk-tail grass, 175.
 Smartweed, 177.
 Societies, 9.
 Soil, 40, 47.
 Sorrel, sheep, 177.
 Sow thistle, annual, 177.
 Spadix, 136.
 Spathe, 136.
 Spelta, 187.
 Spike, 153, 184.
 Spikelets, 183.
 Stamen, 131.
 Starch, 95, 101.
 Stem, 49; endogenous, 59; exo-
 genous, 59; kinds of, 49.
 Stigma, 131, 140.
 Stinkweed, 176.
 Stipule, 76, 84.
 Stock, 123.
 Stomate, 87.
 Stone fruit, 163.
 Storage of food, 99.
 Struggle to live, 4, 6.
 Style, 131, 159.
 Sun energy, 95.
 Sunflower family, 176.
 Survival of fittest, 7.
 Swamp thistle, 177.
 Sweet grass, 175.
 Syngenesious, 137.

 Tendril, 101.
 Thistle, Canada, 177; prairie, 177;
 swamp, 177; Russian, 175.

 Thorns, 101.
 Thyrses, 154.
 Tillandsia, 110.
 Timothy, 194.
 Tissue, 60.
 Torus, 130, 165.
 Tracheid, 65.
 Transpiration, 98, 103.
 Triticum dicoccum, 187; durum,
 187; spelta, 187; vulgare, 187.
 Tumbling mustard, 176.
 "Turkey Red" wheat, 188.
 Twin oats, 189.
 Twiners, 125, 127.
 Two-rowed barley, 182.

 Umbel, 155.
 Undergrowth, 12.

 Valve, 160.
 Variation, 2.
 Verticillate, 84.

 Water-pore, 88.
 Weeds, 172.
 Western quack-grass, 174.
 Western rye-grass, 195.
 Wheat, 186.
 White cockle, 178.
 "White Fife" wheat, 188.
 Whorled, 84.
 Wild barley, 175.
 Wild buckwheat, 177.
 Wild mustard, 176.
 Wild oats, 175.
 Wind travellers, 169.
 Withlow grass, 176.
 Woody fibre, 17.
 Wormseed mustard, 176.
 Wormwood, biennial, 177.
 Wounds of plants, 56.

Date Due

[illegible]

94
QK 47 B15 1921

BAILEY L H LIBERTY HYDE
1858-1954

BEGINNERS BOTANY
39243866 CURR HIST



000003375144

QK 47 B15 1921

Bailey, Liberty Hyde, 1858-1954.
Beginners' botany.

0146838B CURR

HISTORICAL
COLLECTION

2605888

